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Integrated Science Instrument Module (ISIM)

Presentation to the US Community Instrument Concept Study Teams
14 October 98

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ISIM Development

- Programmatics
  - Instrument acquisition plan
- US community instrument concept studies
- Engineering
  - GSFC baseline ISIM feasibility study
  - ISIM technology development

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Science Instrument Procurement Rationale

- concept recomendation by non-advocate review board
  - science driven
  - convened by NASA HQ
- close concept trade early to enable system trades to proceed
  - thermal requirements
  - ISIM technical budgets
- focus technology development spending to retire risk early
- enable well specified “apples to apples” competitive procurement
  - well focused proposals
  - high fidelity selection
- enable wide field of offerors
  - participation in pre-phase not required
- complete selection process prior to single prime RfP

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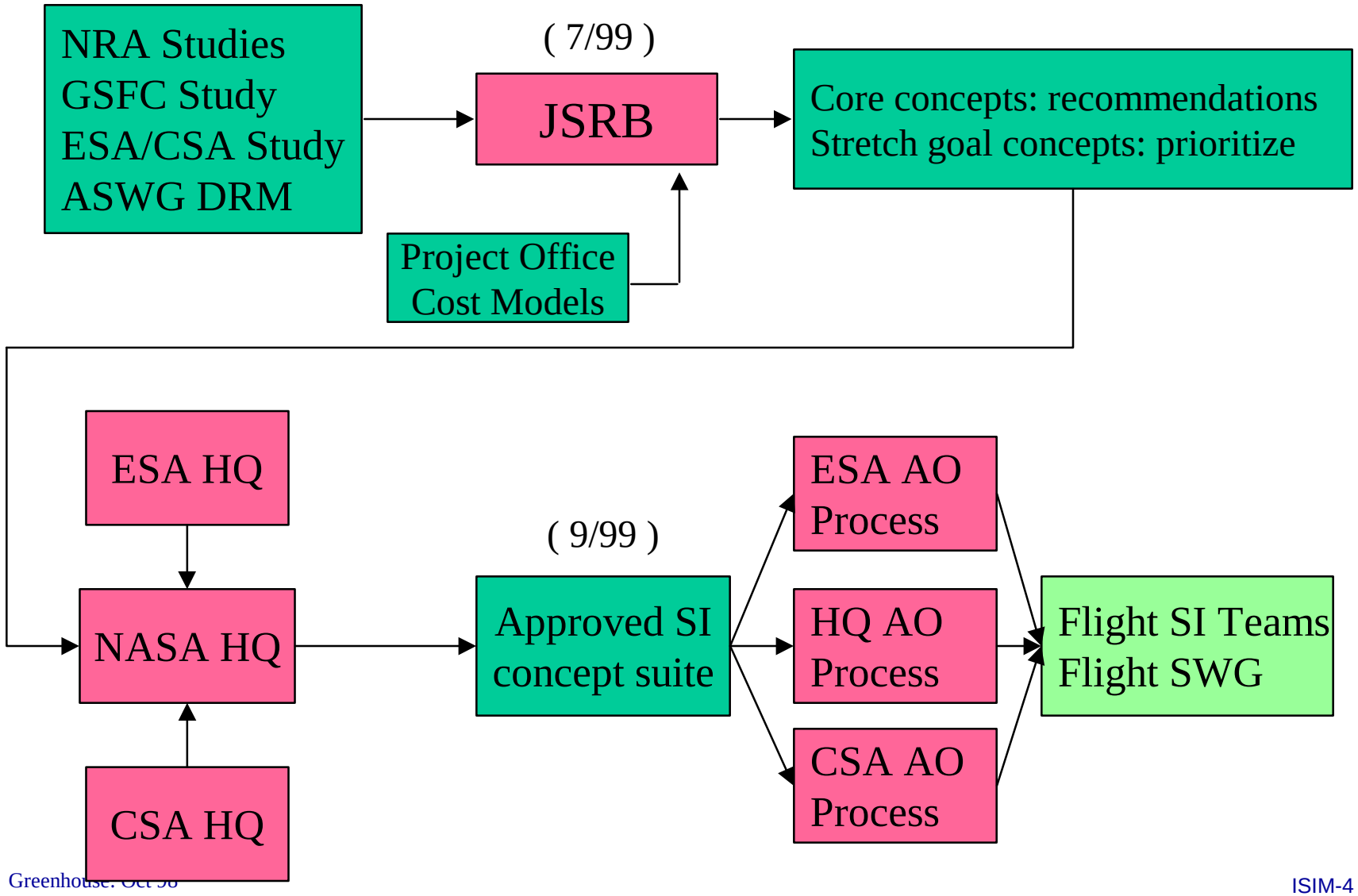
Science Instrument Procurement Process



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Instrument Acquisition Timeline

ISIM Milestones				Year	Month	NGST	ISIM	NGST Milestones
NRA 1: Concept Studies	NRA 1			1998	6	Pre-A	Pre-A	
					7			
					8			
					9			
					10			SRB 2
					11			
					12			Science PNAR
				1999	1			
					2			
					3	A		
					4			
					5			
					6			
Concept Selection: JSRB					7		A	
	JSRB				8			
					9			
NRA 2: Instrument Technologies	NRA 2	Specs	Interface		10			
					11			
					12			
				2000	1			
					2			
Procurement Specifications					3			
					4			
ESA Instrument Commitment					5			
					6		B	
ISIM Interface Definition					7			
					8			
AO Draft Release: Instruments & SWG					9	B		PNAR
					10			
AO Release		AO Solicitation			11			
					12			
Proposals Due				2001	1			
					2			
					3			
Instrument & SWG Selection Complete					4			Single Prime Select
					5			
					6			
					7			
					8			
					9			
					10			
					11			
					12			
						on going	on going	

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Instrument Module Procurement: Critical Path Milestones

- **1. Concept Studies: 6/98 - 6/99 (currently in progress)**
  - US and European community concept studies: ongoing through 6/99.
  - GSFC baseline ISIM system design study: ongoing through FY99.
  - ESA ISIM system design study: ongoing through 8/99.
- **2. Concept Review: 7/99 – 9/99**
  - Joint NASA/ESA Science Review Board (JSRB) selects science floor instrument concepts and prioritizes optional instrument concepts.
  - HQ selects concept suite for solicitation
- **3. Flight Instrument Procurement: 3/00 – 4/01**
  - Procurement specifications for JSRB selected concepts completed 3/00
  - NASA/ESA procurement responsibilities defined: 5/00
    - ESA instrument committed and excluded from NASA solicitation
  - ISIM interface definition: 7/00
  - Flight instrument call for proposals draft release: 9/00
  - Flight instrument call for proposals: 11/00
  - Flight instrument proposals due: 1/01
  - NASA and ESA flight instrument selection complete: 4/01

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JSRB Function

- Advisory to NASA HQ
- Select generic design concepts for instruments that enable the NGST floor science capability.
  - wide field imaging and spectroscopy over 0.6 - 5 microns
  - diffraction limited angular resolution at 2 microns
  - Zodiacal background limited sensitivity
- Prioritize generic design concepts for optional instruments that extend NGST science capability beyond the floor goals.
  - study inputs include cost estimate
- HQ selecting official approves instrument concept suite to move forward for procurment via AO.

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JSRB Function (continued)

- JSRB reports on generic design concepts only.
  - for example:
    - spectroscopy via: Fourier transform imaging vs micro-mirror MOS.
- NRA study reports describing implementation of specific design concepts will be provided as input.
  - JSRB selection of a generic concept does not constitute selection of these specific designs or the teams that produced them.
  - Design study reports are the proprietary property of the authors and will be treated as competition sensitive through the final AO process.
- Concepts that are not recommended for enabling the science floor may be recommended as optional instruments.

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Instrument Module Procurement: Other Schedule Items

- Enabling Technologies and Modeling Studies: 10/99 – 10/00
  - Schedule place holder NRA for community studies focusing on enabling technologies and performance modeling for JSRB selected instrument concepts.
- Top level OTA and ISIM thermal requirements flow down complete 7/00
  - trade closure enabled by JSRB selection 6 months prior
  - required for prime down select
- Flight SWG AO coupled with instrument NRA
  - selects SWG scientists not affiliated with instrument teams
  - Flight SWG selection 4/01
    - science leadership team in place ~ 1 year before NAR
      - SWG AO scientists, SI PIs, STScI & GSFC PS team

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US Community Instrument Concept Studies

Solicited from external community via NRA with NASA HQ peer review

Six teams, selected during Jun 98, 1 year performance period

- J. Bechtold, T. Greene: U. of Arizona & Lockheed Martin Corp.
  - 0.3 - 40 micron imaging, spectroscopy, and ISIM layout
- J. Graham: U. of California & ITT Industries & Lawrence Livermore Labs
  - 1 - 15 micron Fourier transform imaging spectroscopy
- J. MacKenty: STScI/ Ball Aerospace/ GSFC
  - 1 - 5 micron multi-object spectroscopy with MEMS micro-mirrors
- H. Moseley: GSFC
  - MEMS micro-shutter aperture control for multi-object spectroscopy
- G. Serabyn: JPL
  - 5 - 28 micron camera/spectrometer and Sorption cryo-cooler
- J. Trauger: JPL
  - 5 - 30 micron high contrast coronagraph with deformable mirror

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CSA Instrument Concept Studies

- Develop and prototype SI subsystems
- Three PIs Selected by CSA
- Studies to be completed by June 99, and involve international collaboration

  - S. Morris (HIA): Integral Field Spectroscopy
  - D. Crampton (HIA): Multi-Object and Integral Field Spectroscopy
  - P. Hickson (UBC): Optical Imagery

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ESA Instrument Concept Studies

- Consortium selected by ESA to perform a trade study of integral field and multi-object spectrograph options
- A detailed design study will be performed on one option.
  - O. Le Fevre (PI), LAS, Marseille, France
  - R. Bacon, Observatoire de Lyon, France
  - R. Davies, Durham University, UK
  - R.S. Ellis, Cambridge University, UK
  - G. Monnet, European Southern Observatory, Garching, Germany
  - N. Thatte, MPE, Garching, Germany
  - T. de Zeeuw, Leiden Observatory, the Netherlands
- Details will appear on: http://www.astrsp-mrs.fr/www/ngst2.html

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GSFC Baseline ISIM Design Study

- Study goals:
- Demonstrate mission science feasibility,
- Assess ISIM engineering and cost feasibility,
- Identify ISIM technology challenge areas,
- Define ISIM interfaces ,
- Enable smart customer procurement of the ISIM.

- Architecture constraints:
- Integration with the “Yardstick” and other NGST 8 m architectures that are intended for packaging in an EELV or Ariane 5 meter class fairing.

- Ongoing progress can be monitored via the NGST web site: http://ngst.gsfc.nasa.gov/

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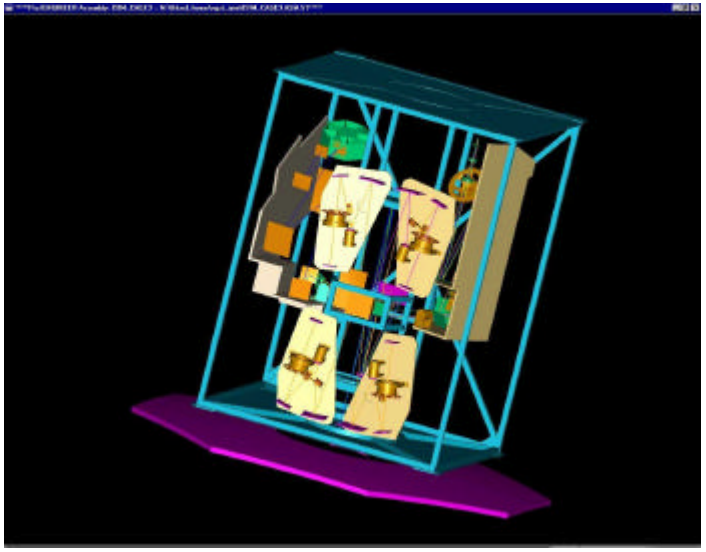
Baseline ISIM design evolution

- 1996
  - single integrated instrument
  - top level concept only
- 1998
  - modular instrument
  - detailed engineering model
    - opto-mechanical layout
    - thermal constraints
    - OTA constraints
    - package volume constraints



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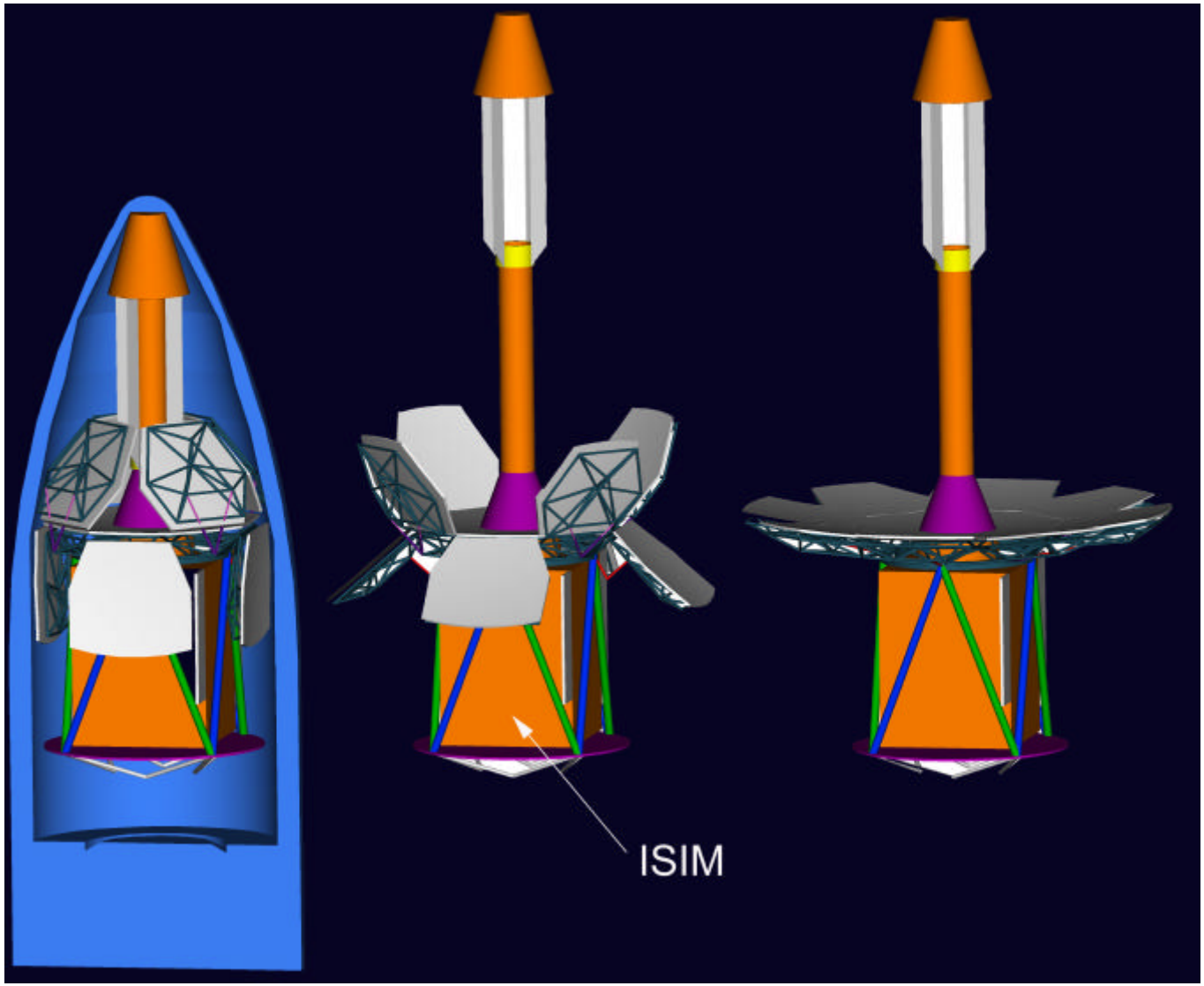
NGST 8m: EELV Medium 5m Fairing



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ISIM Baseline Science Instruments

Instrument	Wavelength (μm)	Bandwidth	FPA	Pixel Pitch	Plate Scale (10^{-3} arc-sec)	Aperture Control (arc-min)
Near-IR Camera (1 of 4[1])	0.6 – 5.3	R = 2,5 fixed filters R = 50,200 tunable filters	4096 x 4096	27	29	quad-beam divider: four 2 x 2 fields coronagraph mask[2]
Near-IR Spectrometer	0.6 – 5.3	R = 300, 3000 gratings	4096 x 4096	27	100	reflective slit mask: 2048 x 2048 micro-mirror array, 100 μm pixels
Mid-IR Camera/Spec	5 – 28	broad-band filters grisms, cross-disperser	1024 x 1024	27	230	slit selection + 2 x 2 camera

1. A quad-beam divider (pyramid mirror) apportions a 4 x 4 arc-min field of view over 4 identical cameras.
2. Holes in pyramid mirror facets used to form simple coronagraph.

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OTA and ISIM System Optical Schematic

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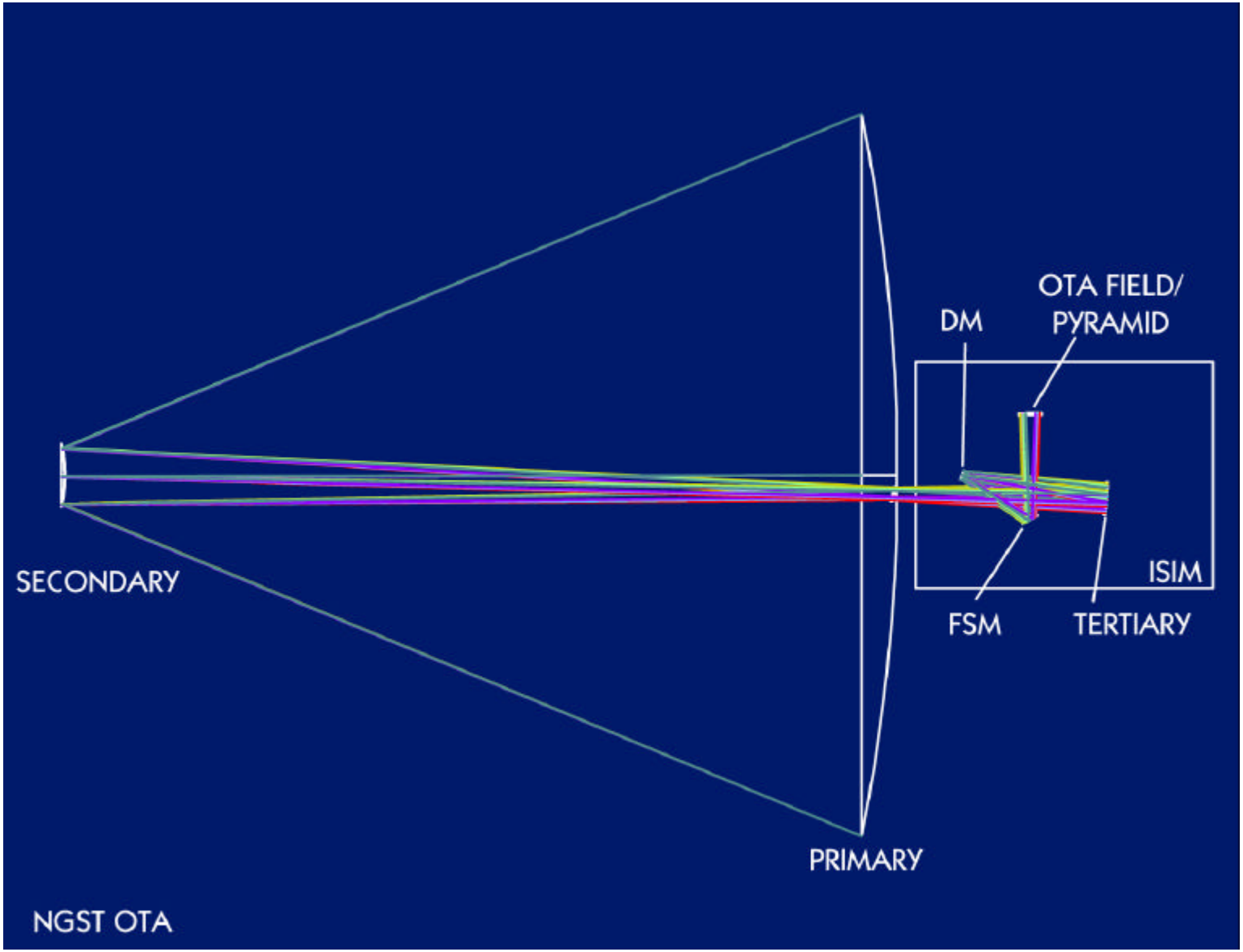

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NGST ISIM Focal Plane Layout

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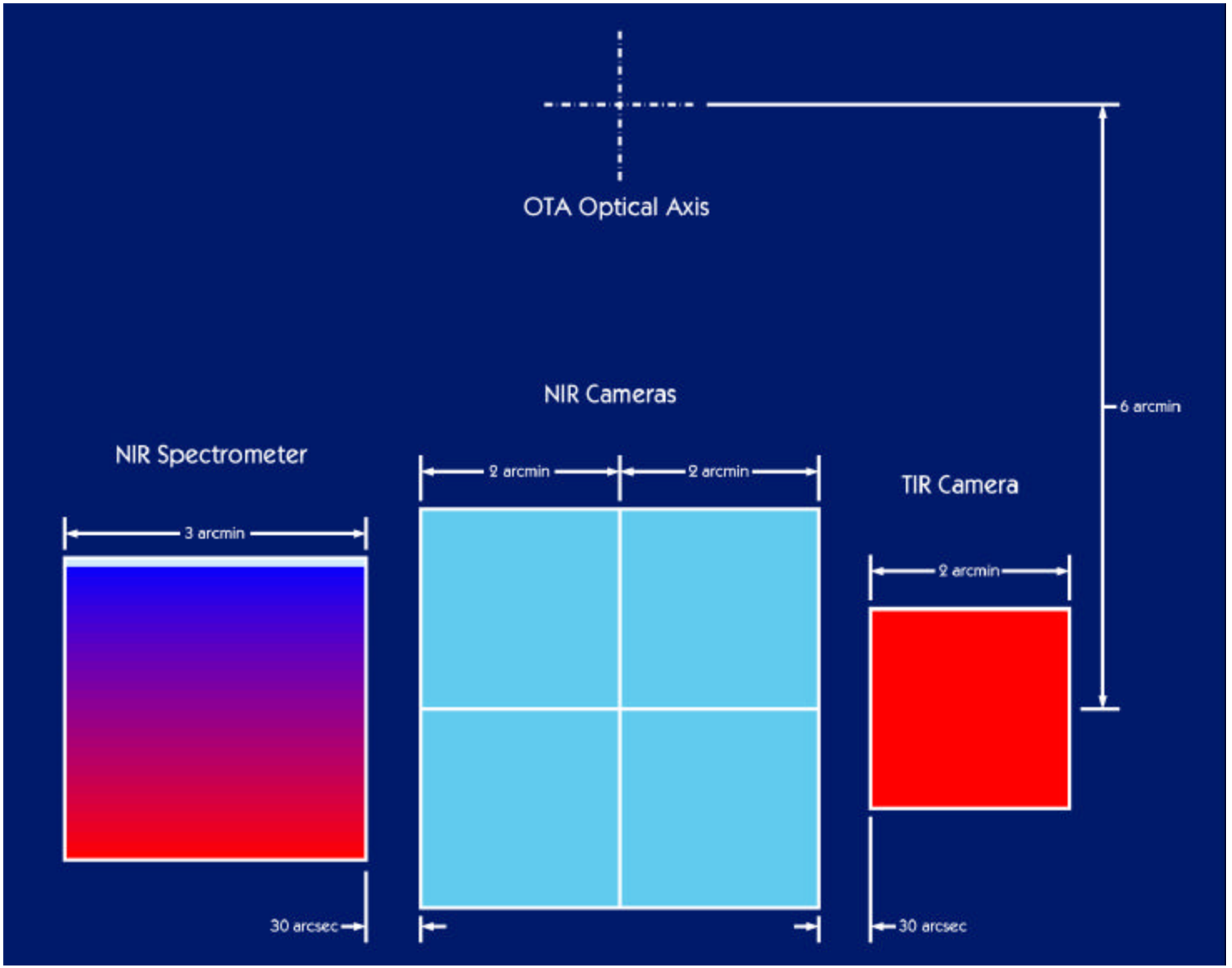

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RMS Wavefront Error Vs Field Position

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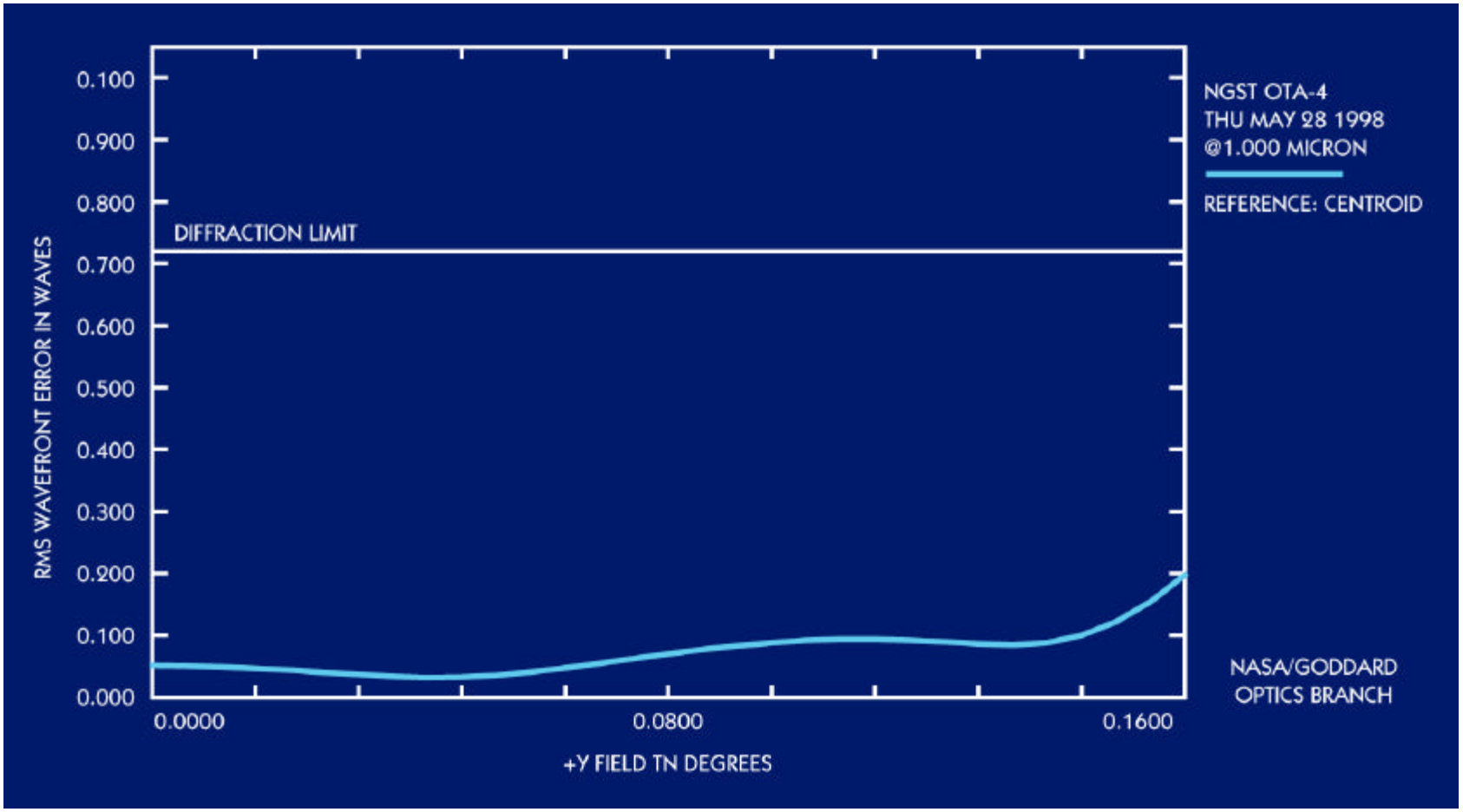

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The ISIM instruments are located in an off-axis position.
This configuration yields excellent image quality.

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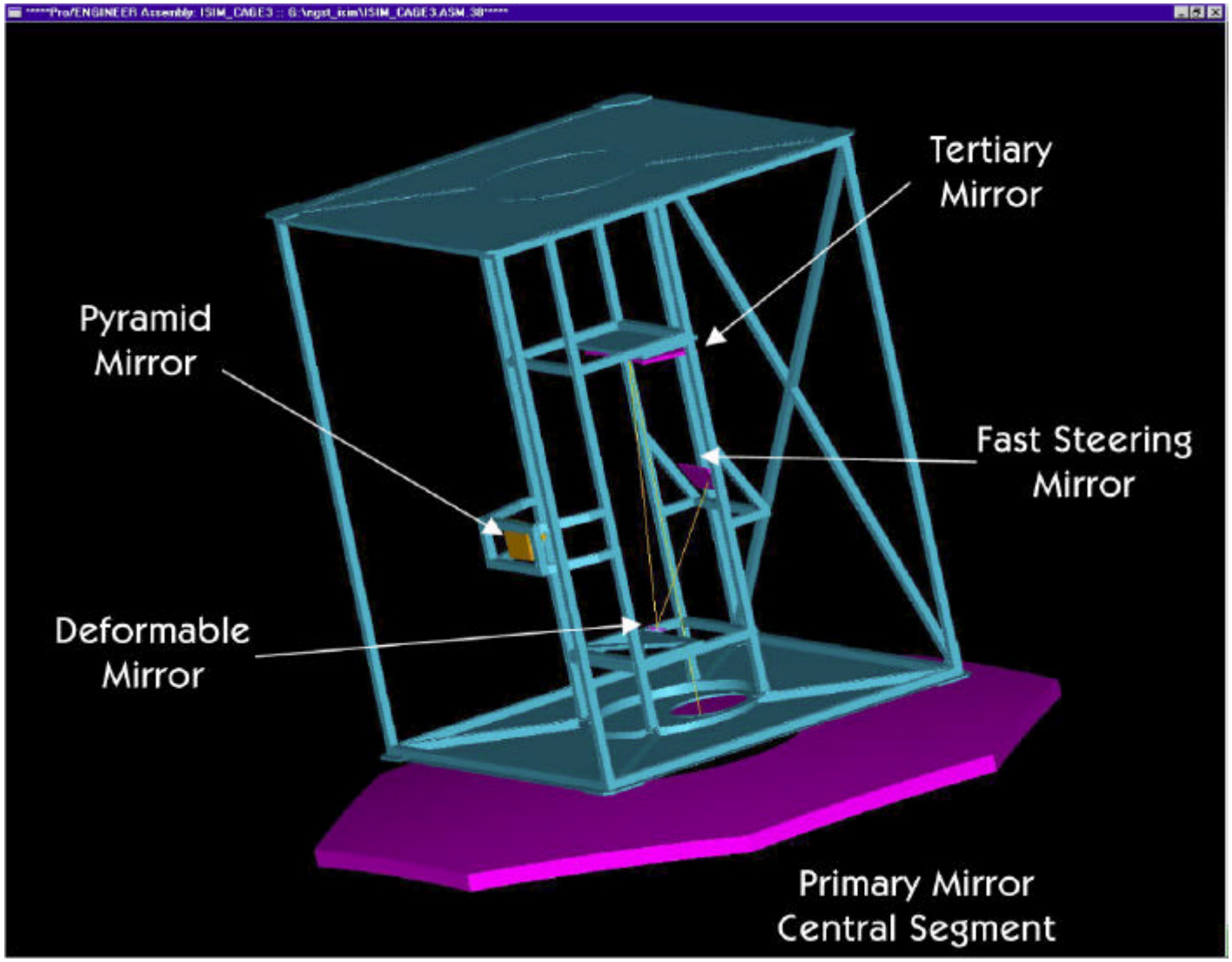

The OTA tertiary mirror, deformable and fast steering mirror assemblies, and pyramid mirror integrate into the ISIM in a modular fashion.

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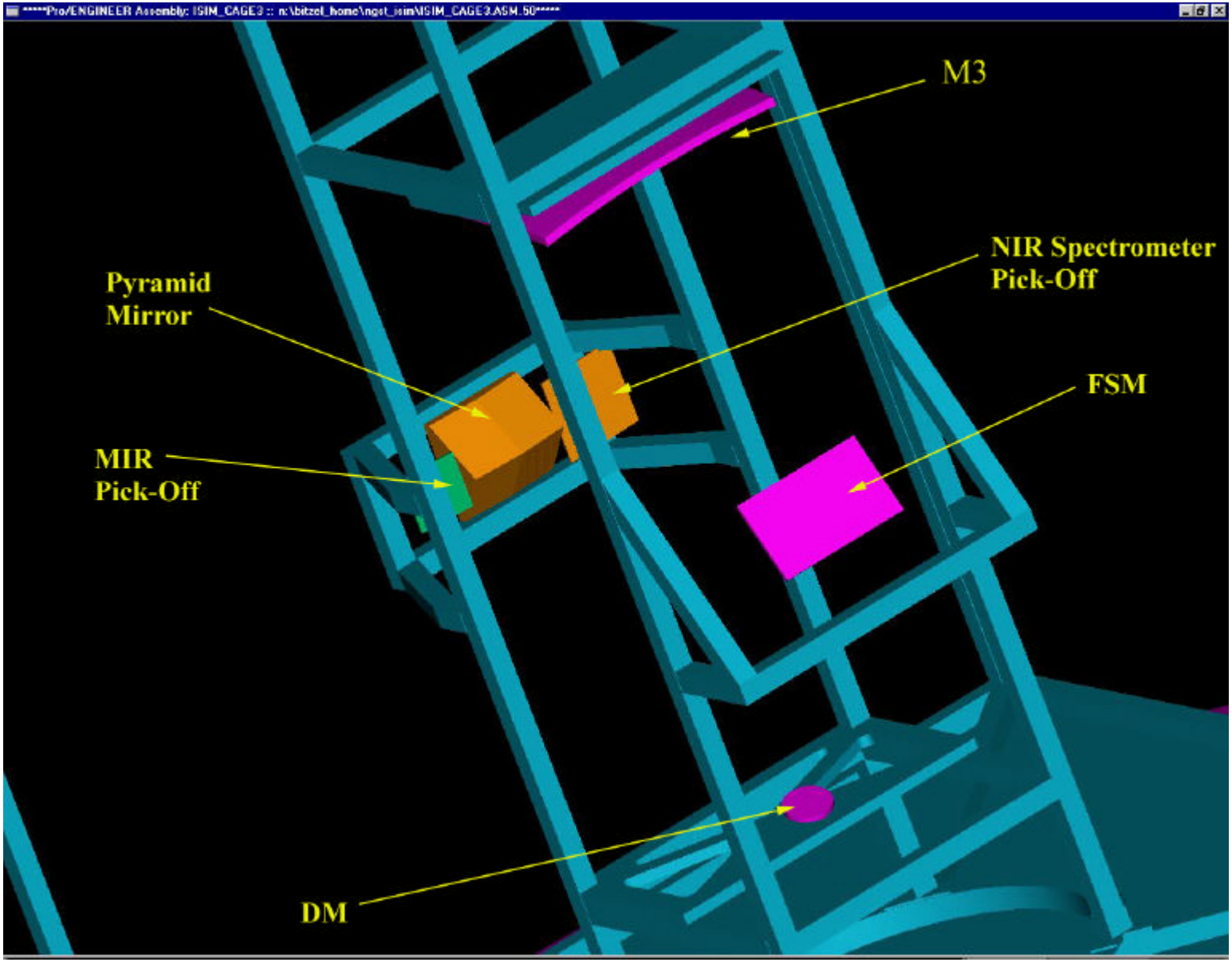

Near-IR Wide Field Camera Optical Schematic

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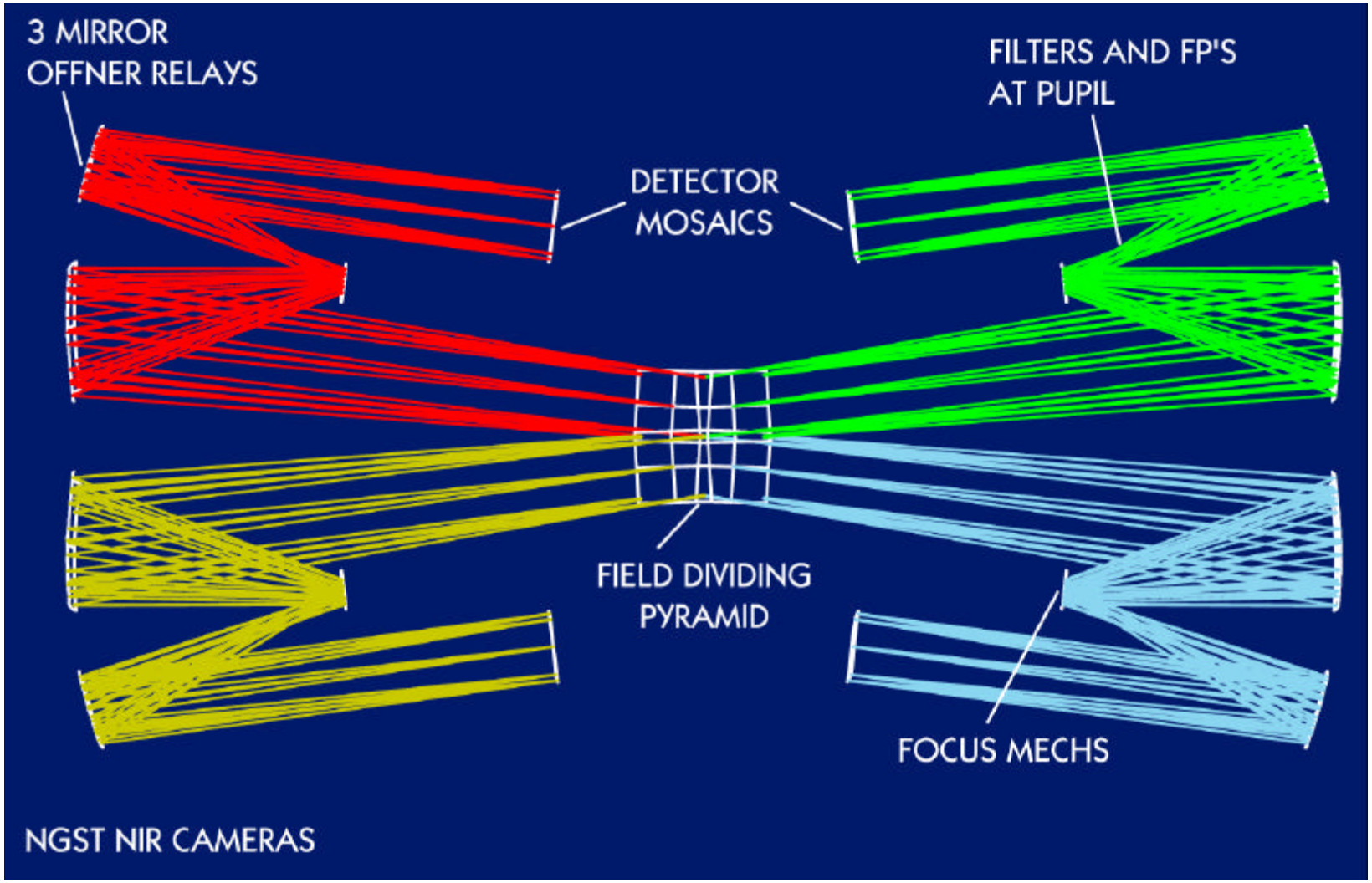

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Near-IR Wide Field Camera Optical Schematic

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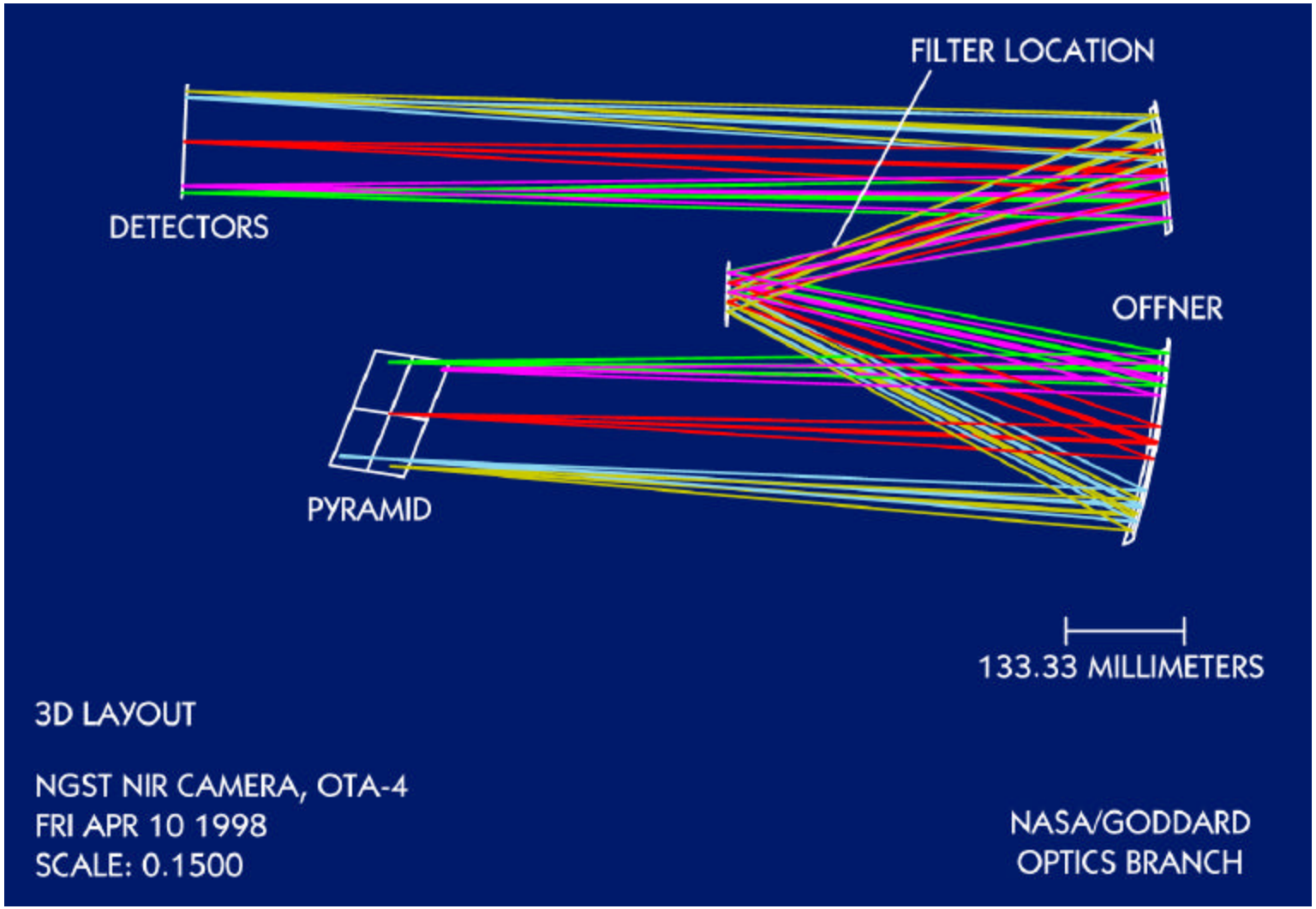

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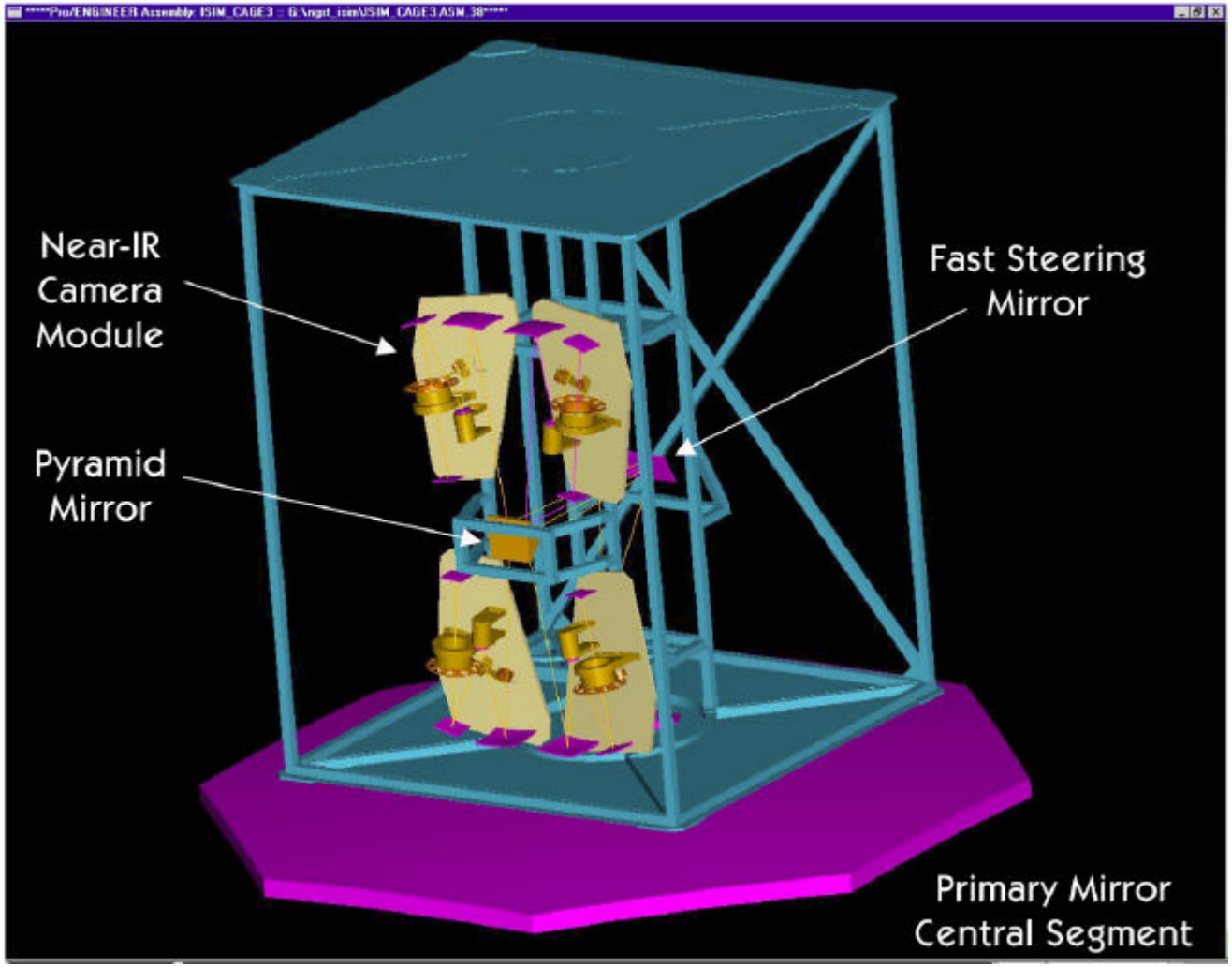
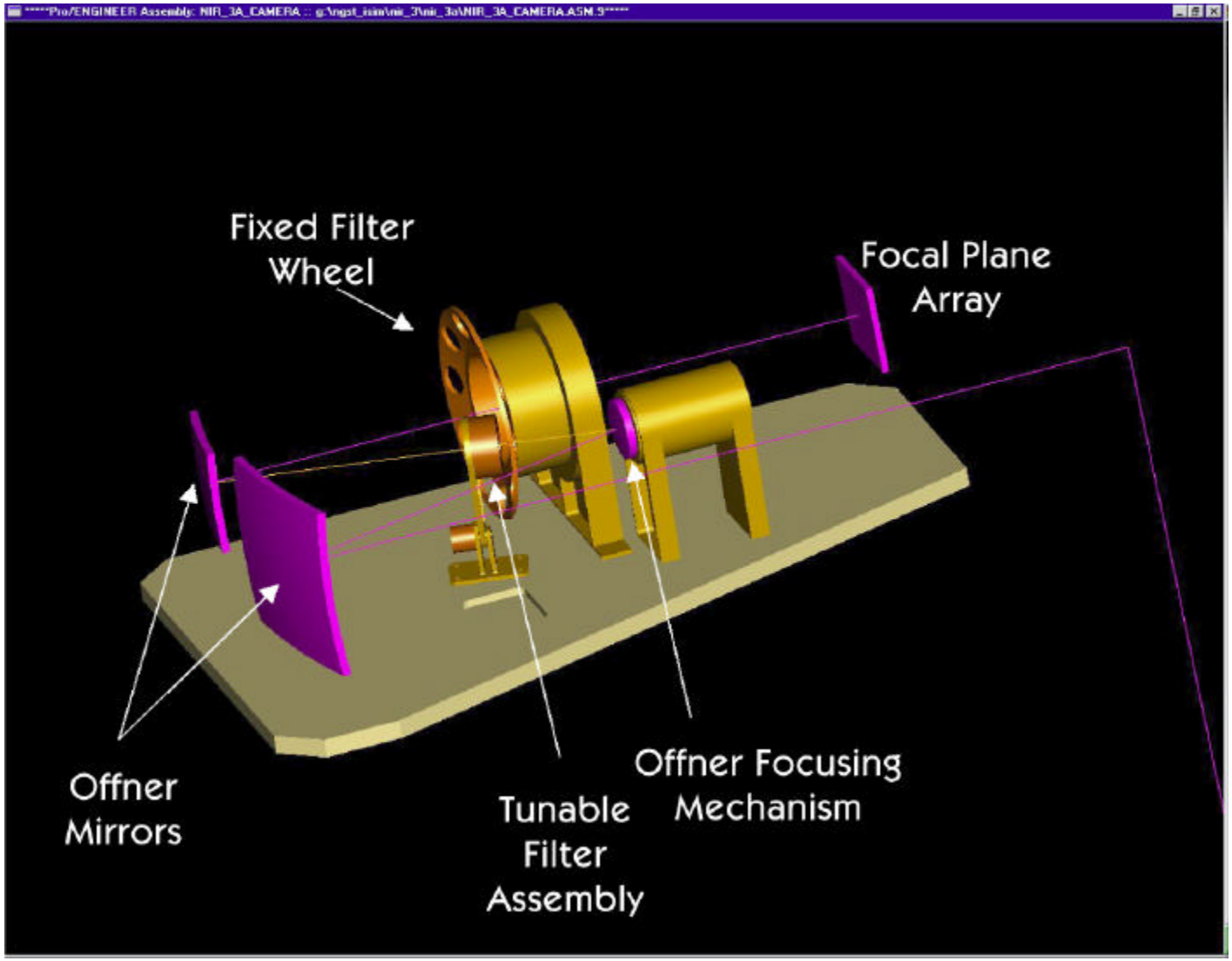


The ISIM near-infrared wide field camera employs a pyramid beam divider to apportion a 16 square arc-min field of view over four identical camera modules. Each module utilizes a 4096 x 4096 focal plane array covering 4 square arc-min.



Each camera channel includes a focusing Offner relay, filter wheel, and retractable tunable filter.

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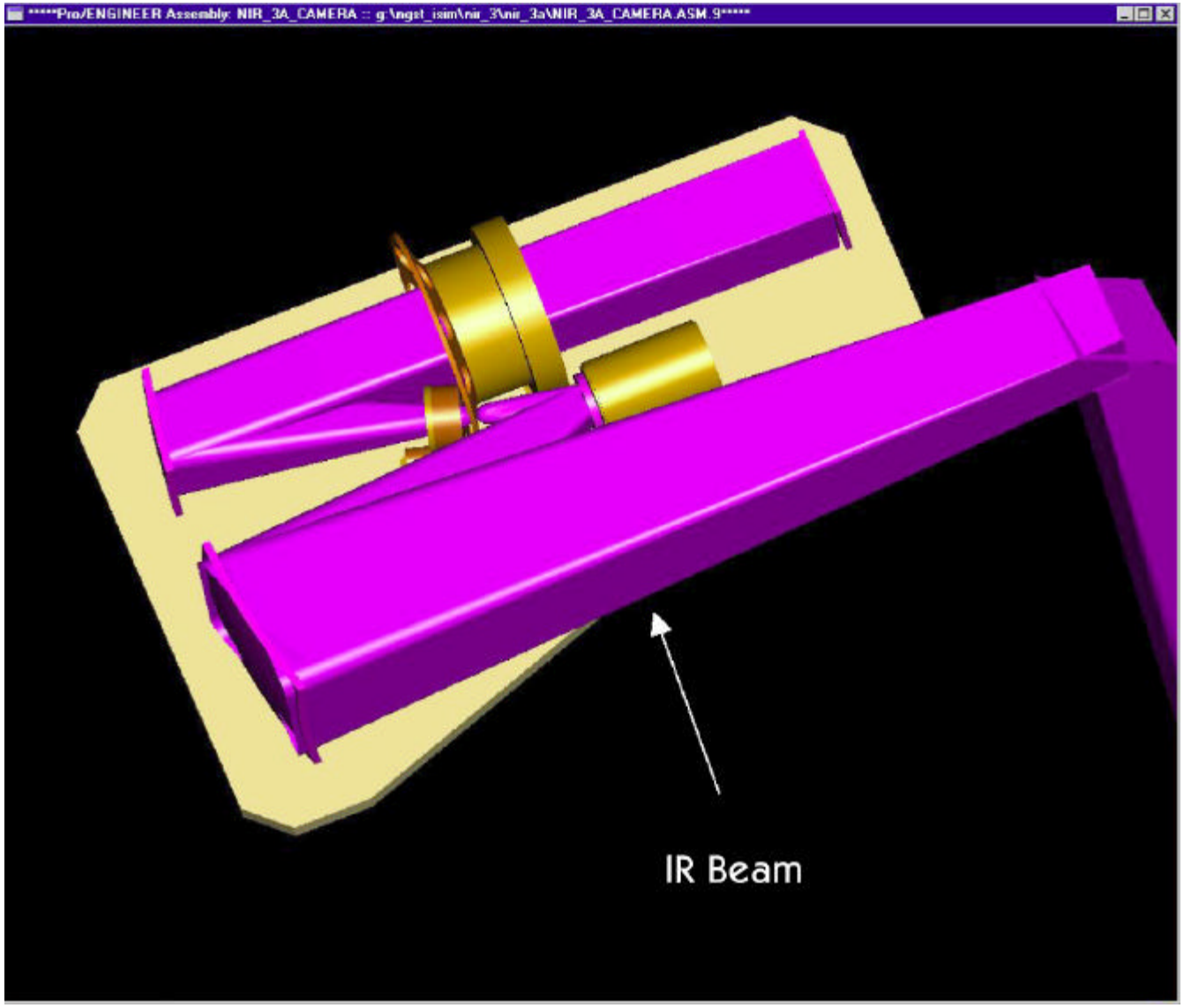

Near-infrared camera module with solid model beams.

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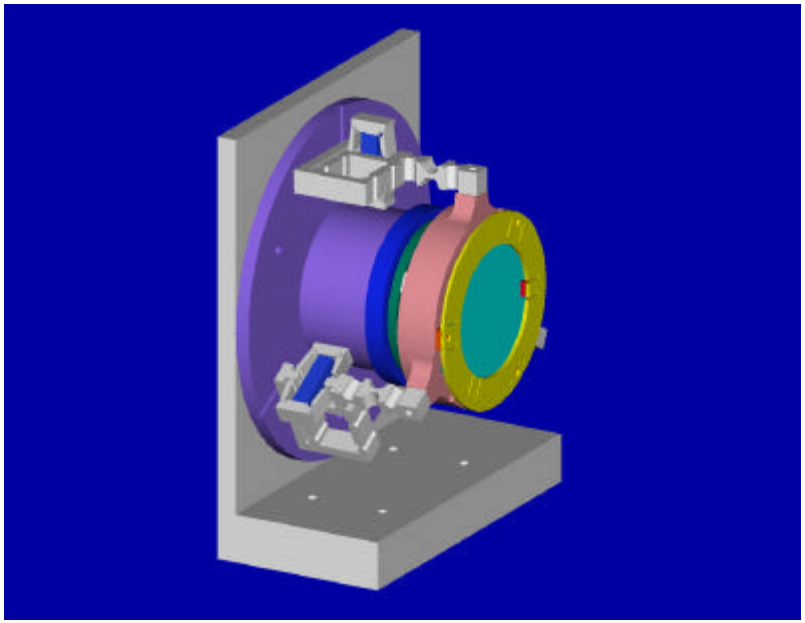
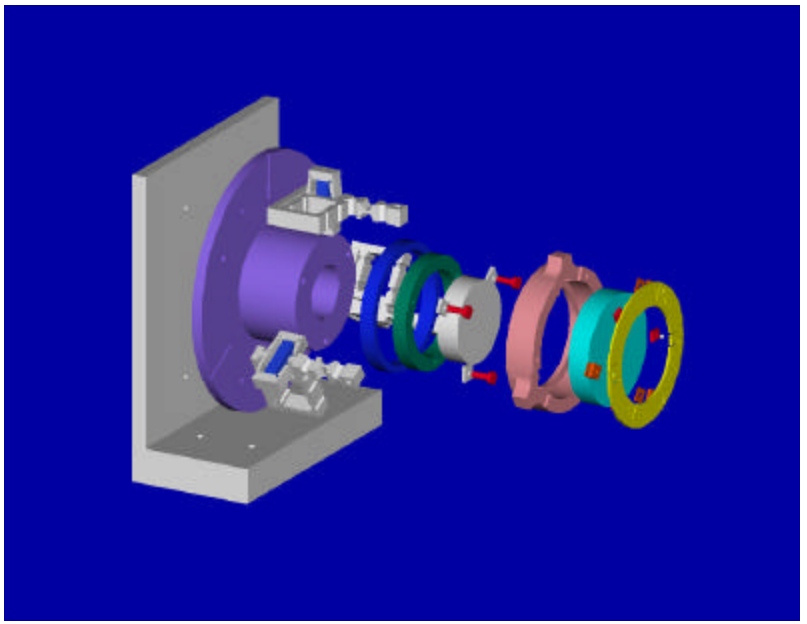
Demonstrator Unit for Low Order Cryogenic Etalon (DULCE)

- Prototype tunable filter for NGST wide field imagery at 50 < R < 200
- Under development by GSFC and Northrop Grumman Corp
- ~ 100 K in CY 98 funded by GSFC DDF and RTOPs





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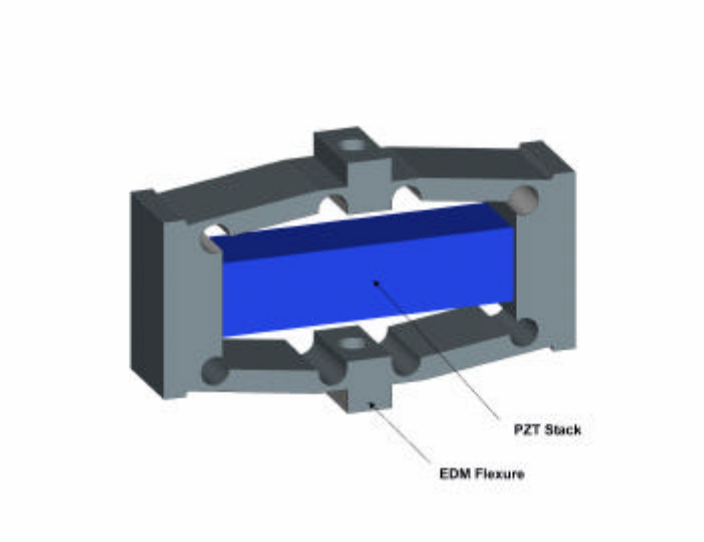
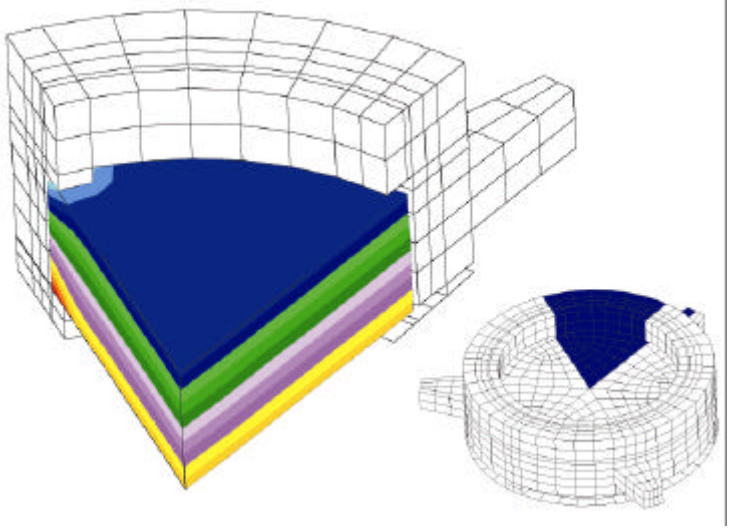
DULCE Technology Challenge Areas

- Low phase dispersion, low absorption dielectric mirror coatings for 1-5 microns
- Long stroke nm precision actuators for 30K operation
- Sub-micron gap etalon assembly for 30K operation
- High precision position servo control





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Mid-IR Camera/Spectrometer Optical Schematic

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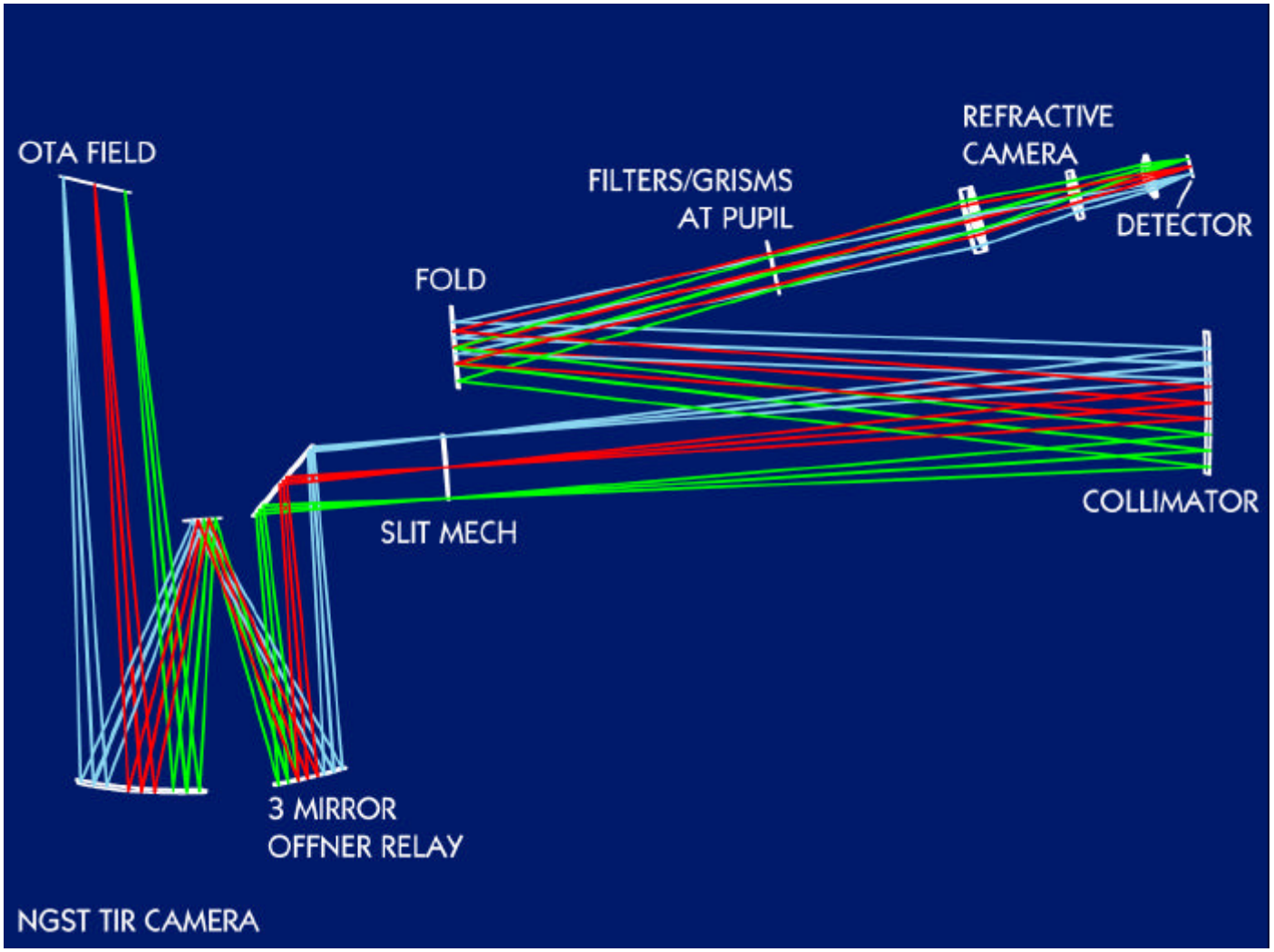

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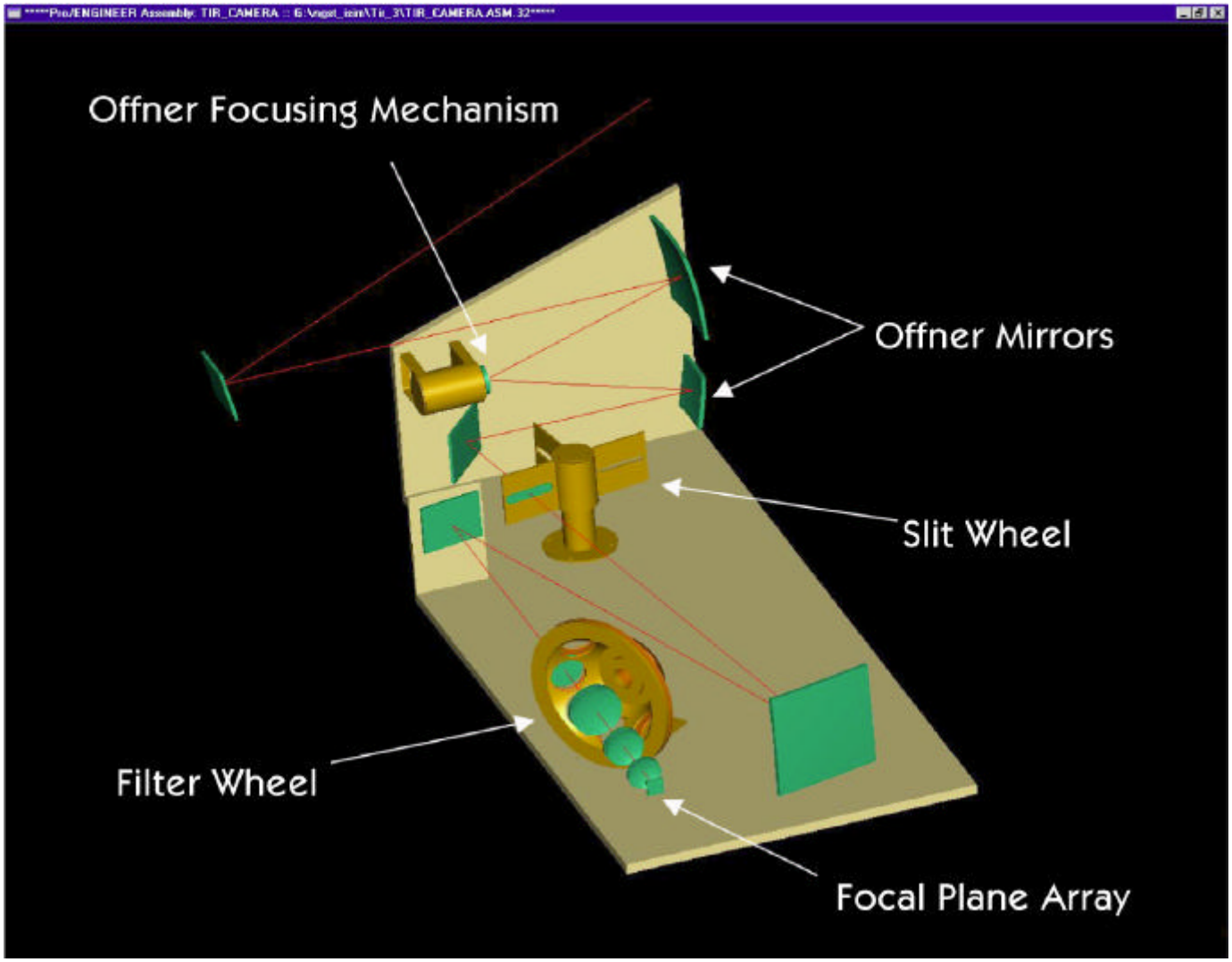

The mid-infrared camera/spectrometer module utilizes a 1024 x 1024 focal plane array and contains selectable slits, filters, and cross-dispersed grisms.

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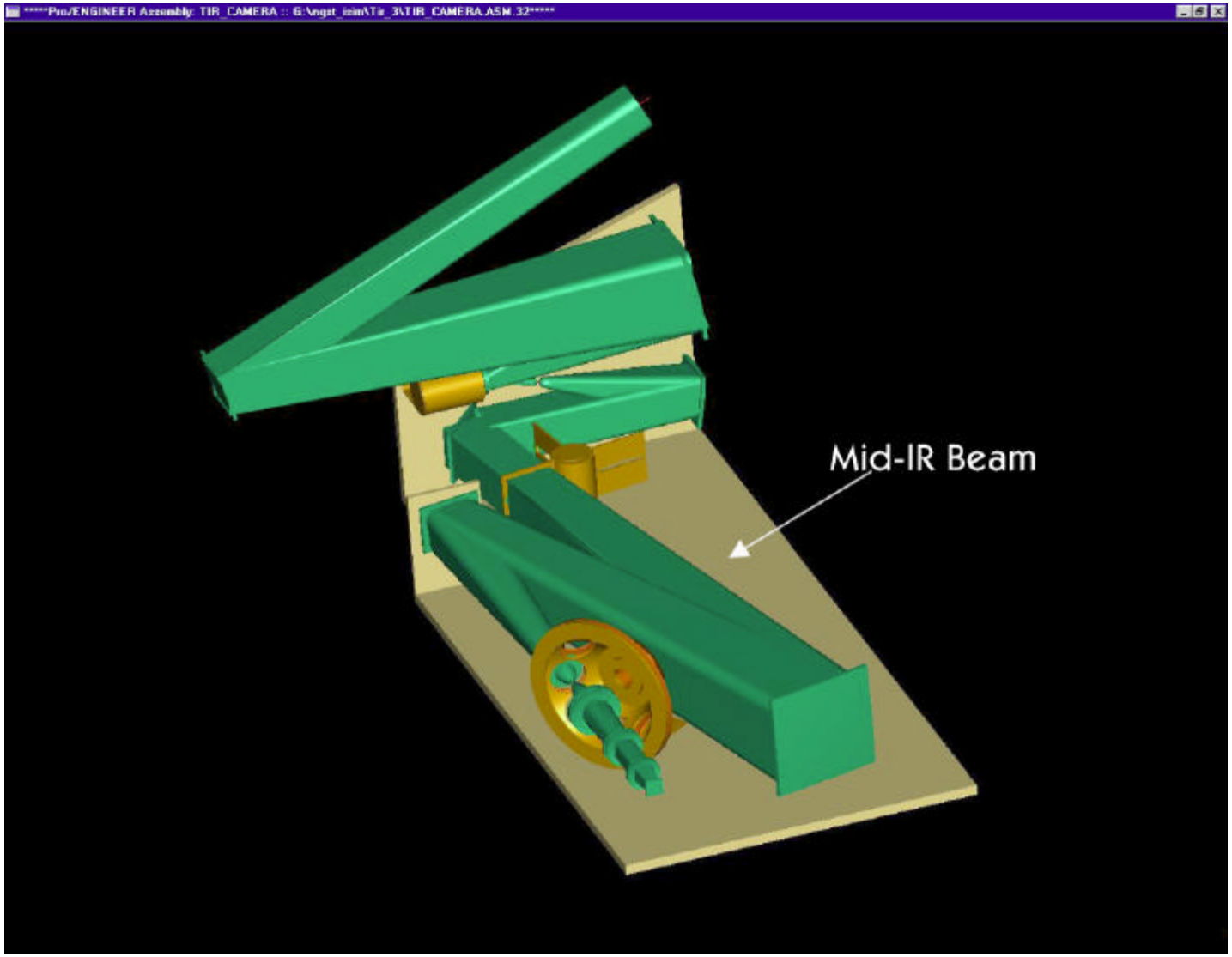

Mid-infrared camera/spectrometer module with solid model beams.

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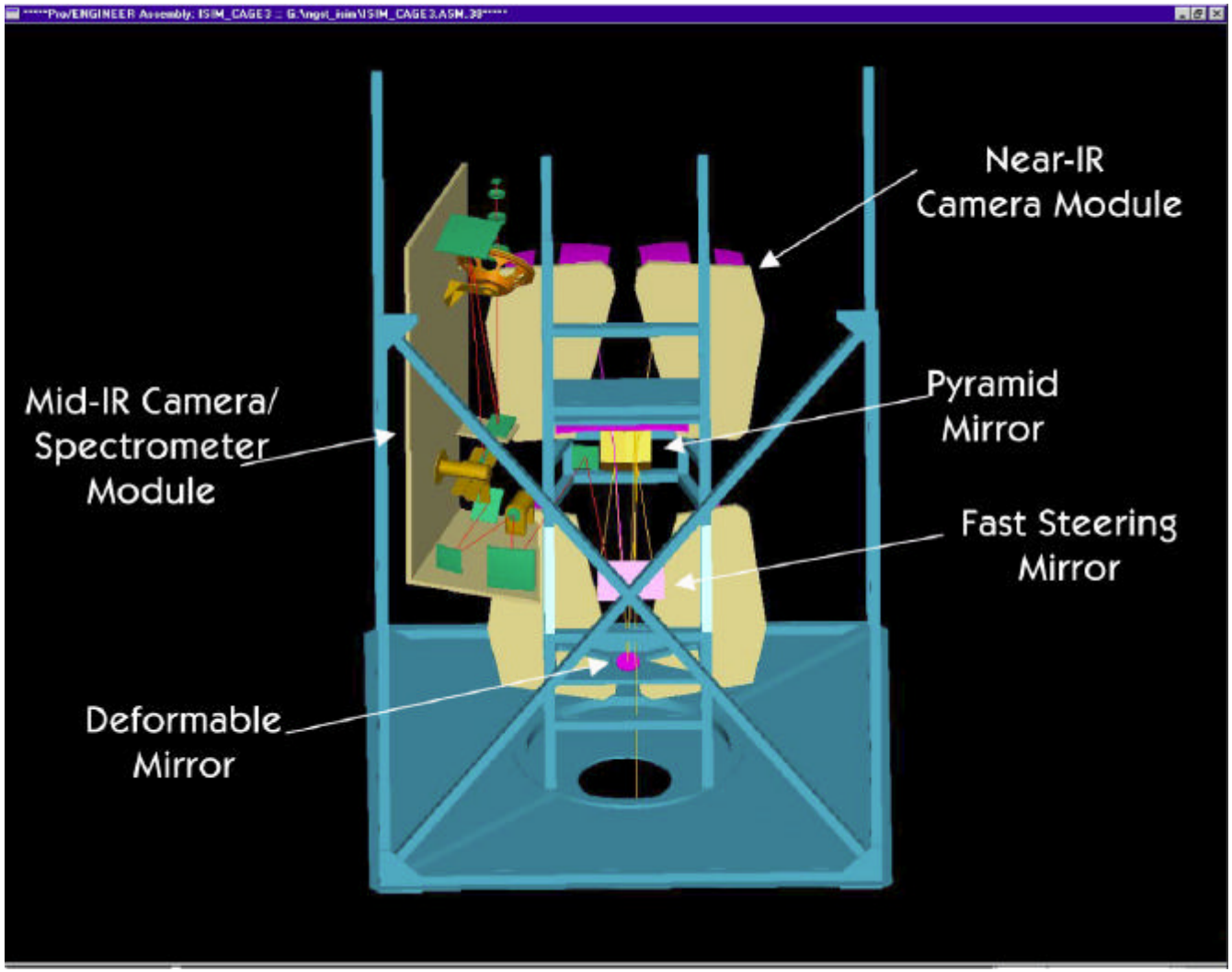

The near-ir camera and mid-ir camera modules integrate into the ISIM in a modular fashion. Near-ir spectrometer not shown.

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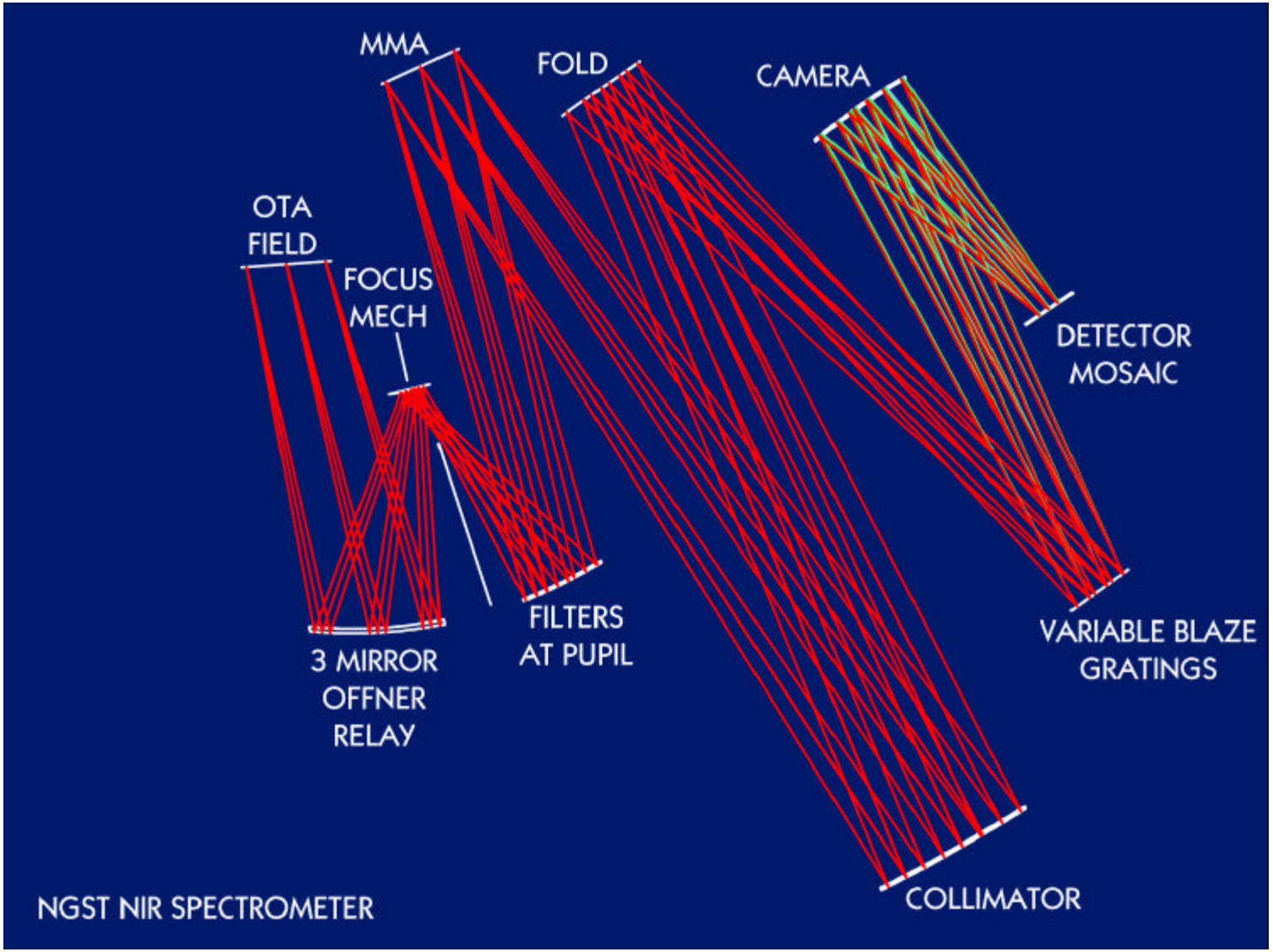
Near-IR Micro-Mirror Array Spectrometer Optical Schematic



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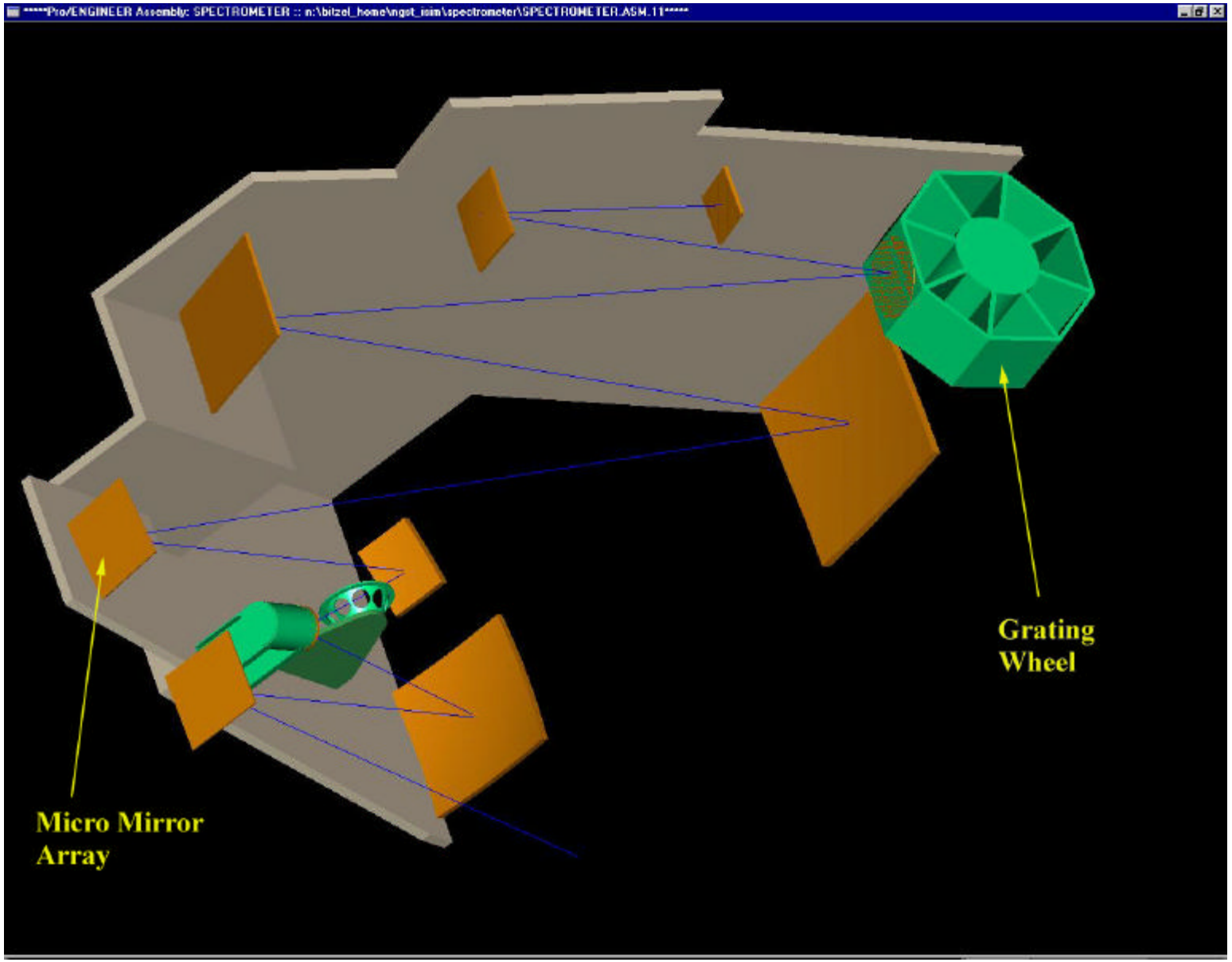
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Grating Wheel
Micro Mirror Array

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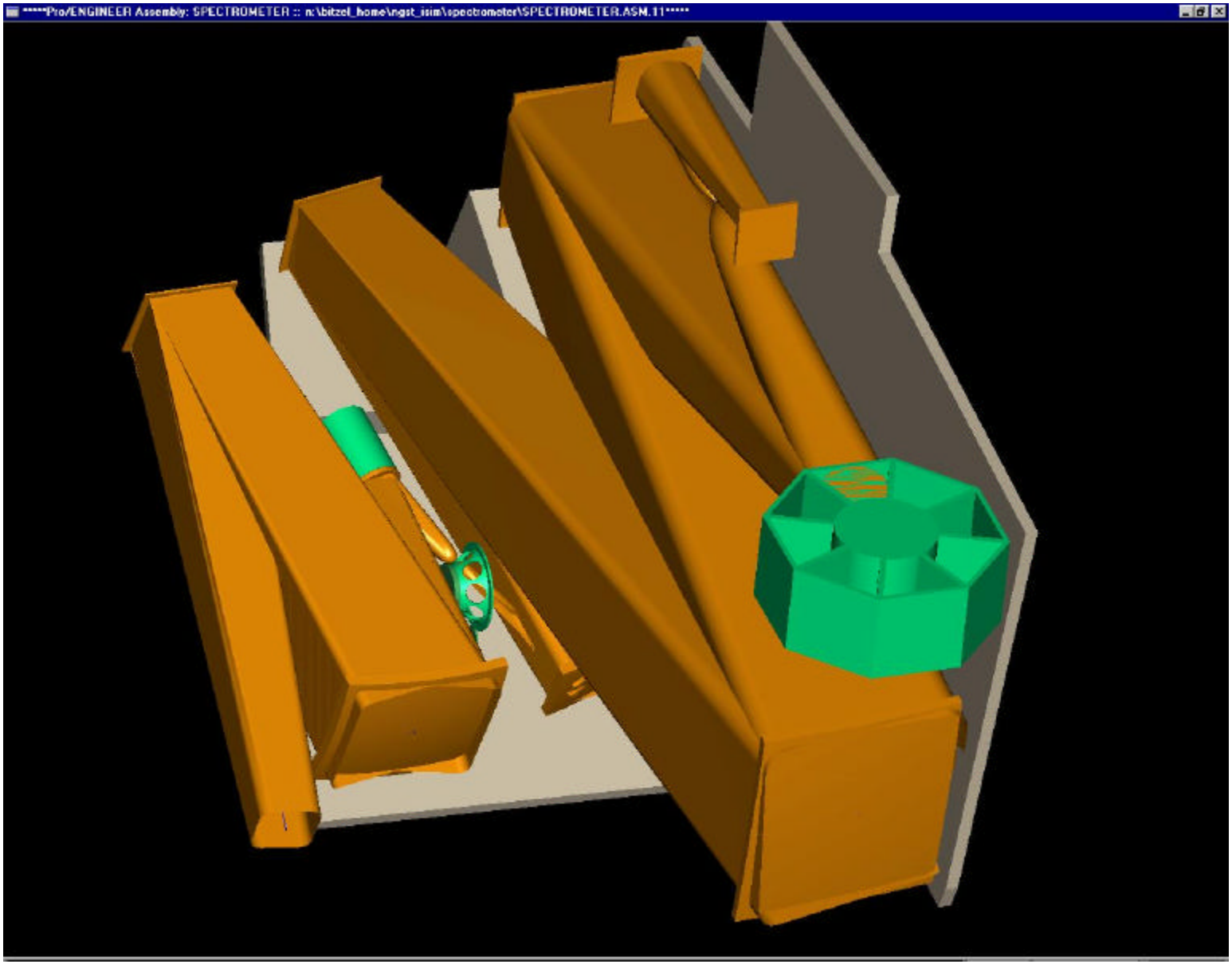

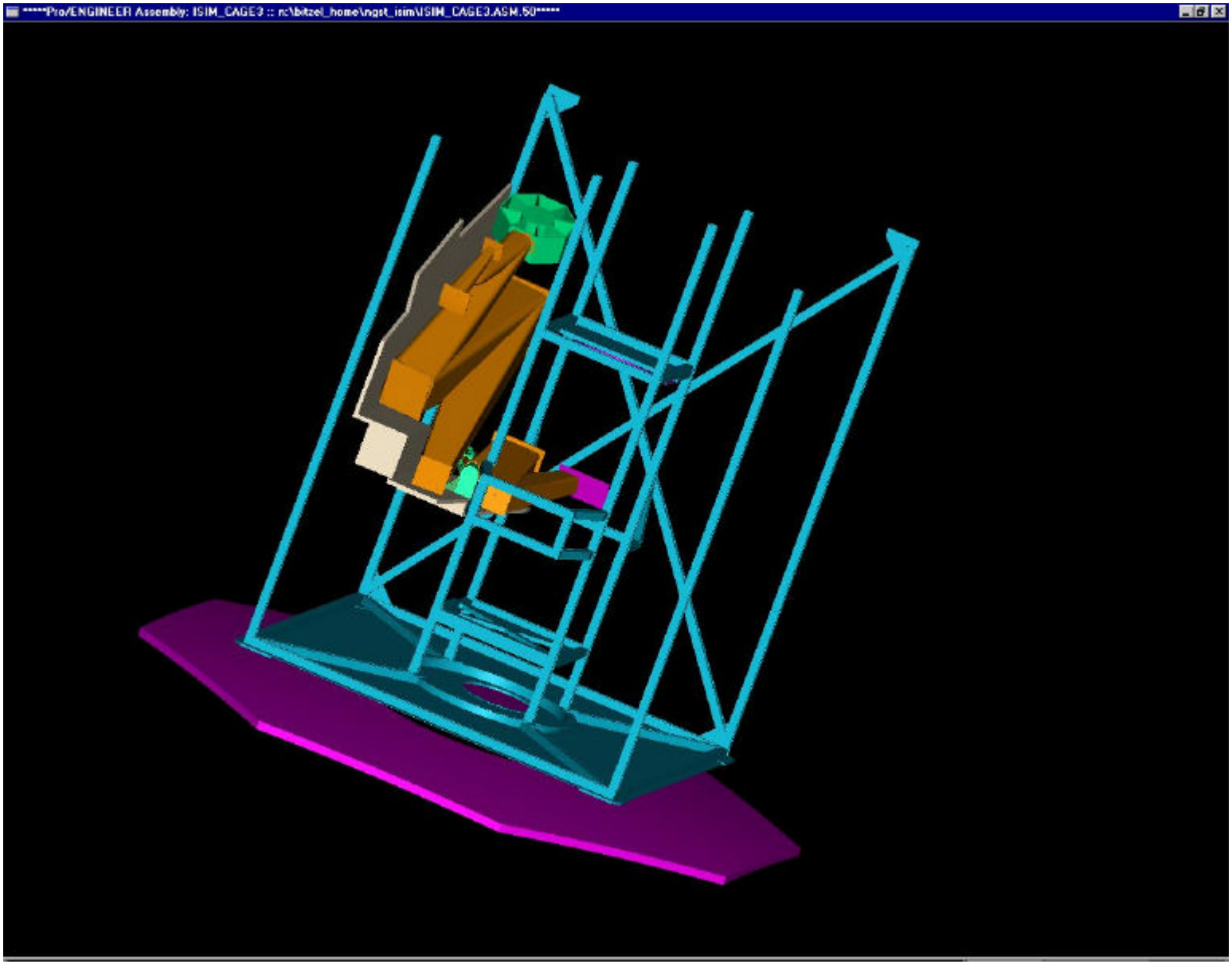
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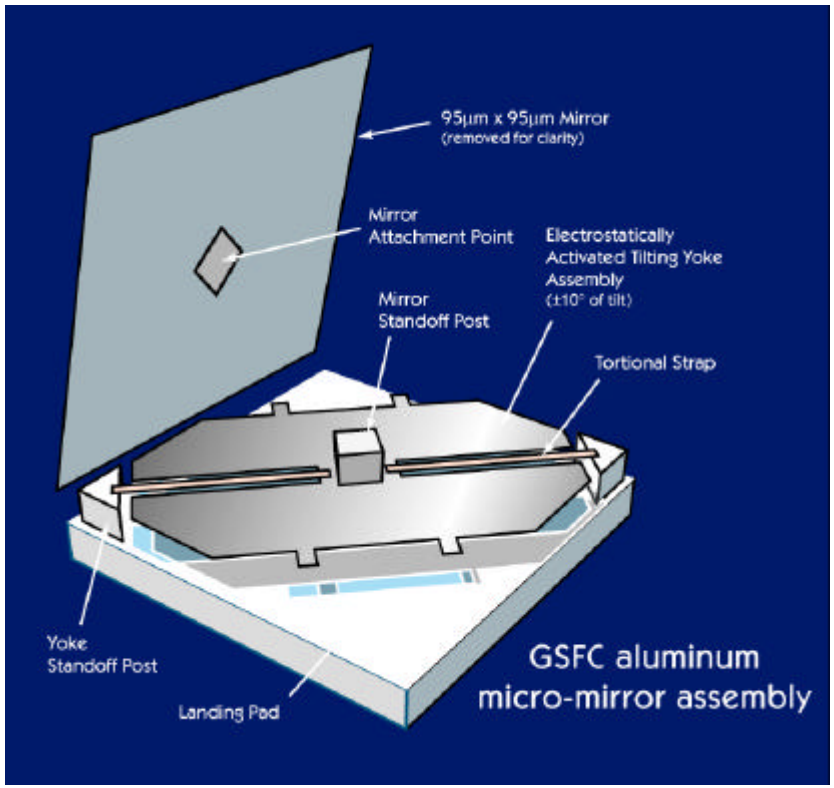
MEMS Sensor Optics

Cryogenic Micro-Mirror Arrays for Multi-Object Spectroscopy

- GSFC all aluminum design
  - prototype development started Jan 98
- Sandia National Labs all silicon design
  - prototype development to start Oct 98
- 30 K operating temperature
- 100 micron pixel pitch
- surface micro-machining
- low voltage electrostatic actuation
- scalability goal: 2048 x 2048



STScI NGST-MOS Study

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Performance Exhibited By Current Detectors Is Near NGST Goals

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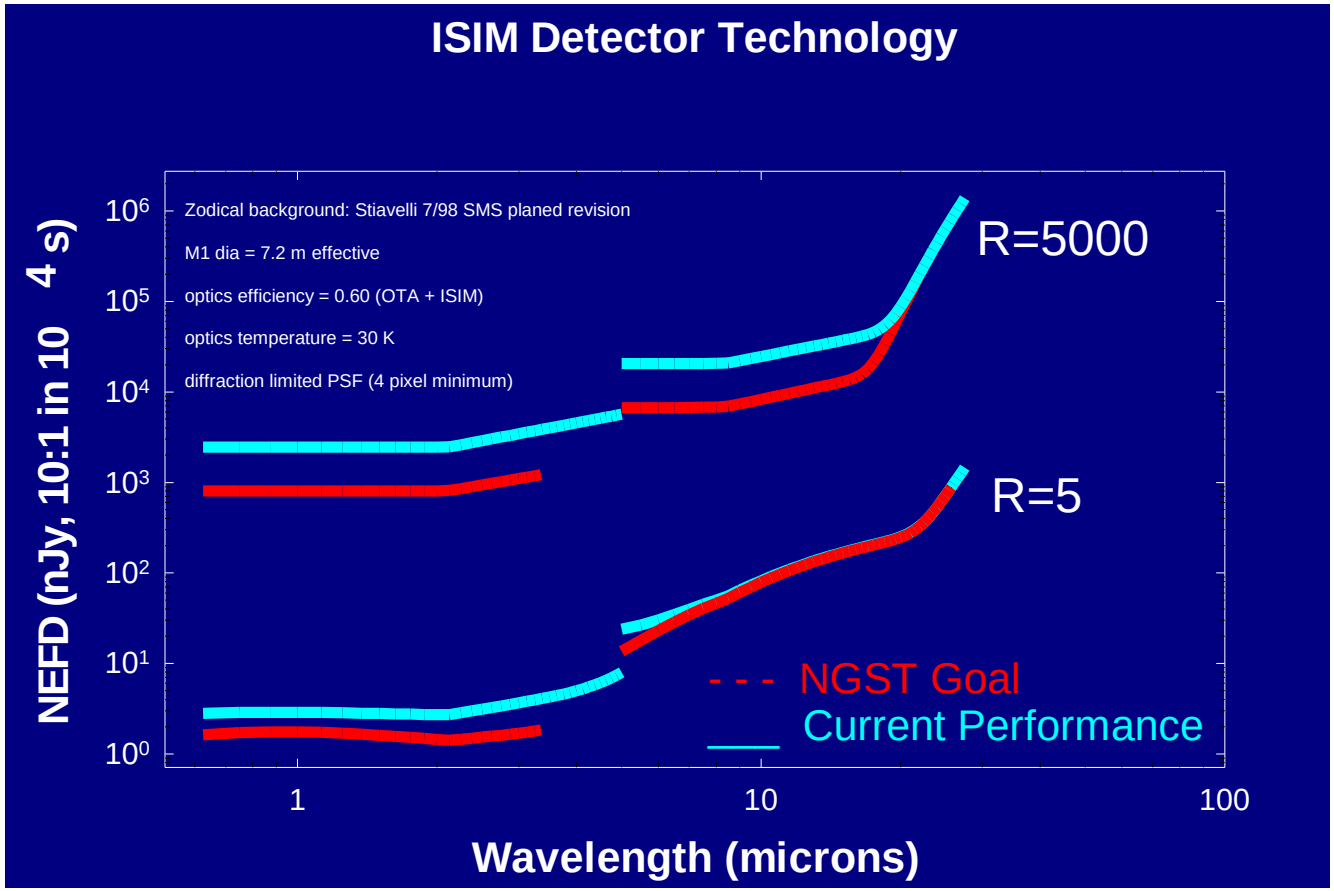

	QE	Read Noise (e) multiple read	Dark Current (e/s)
Alladin InSb	0.8	15	0.1
Near-IR goal	0.8	3	0.02
Current Si:As	0.5	8	10
Mid-IR goal	0.5	3	1

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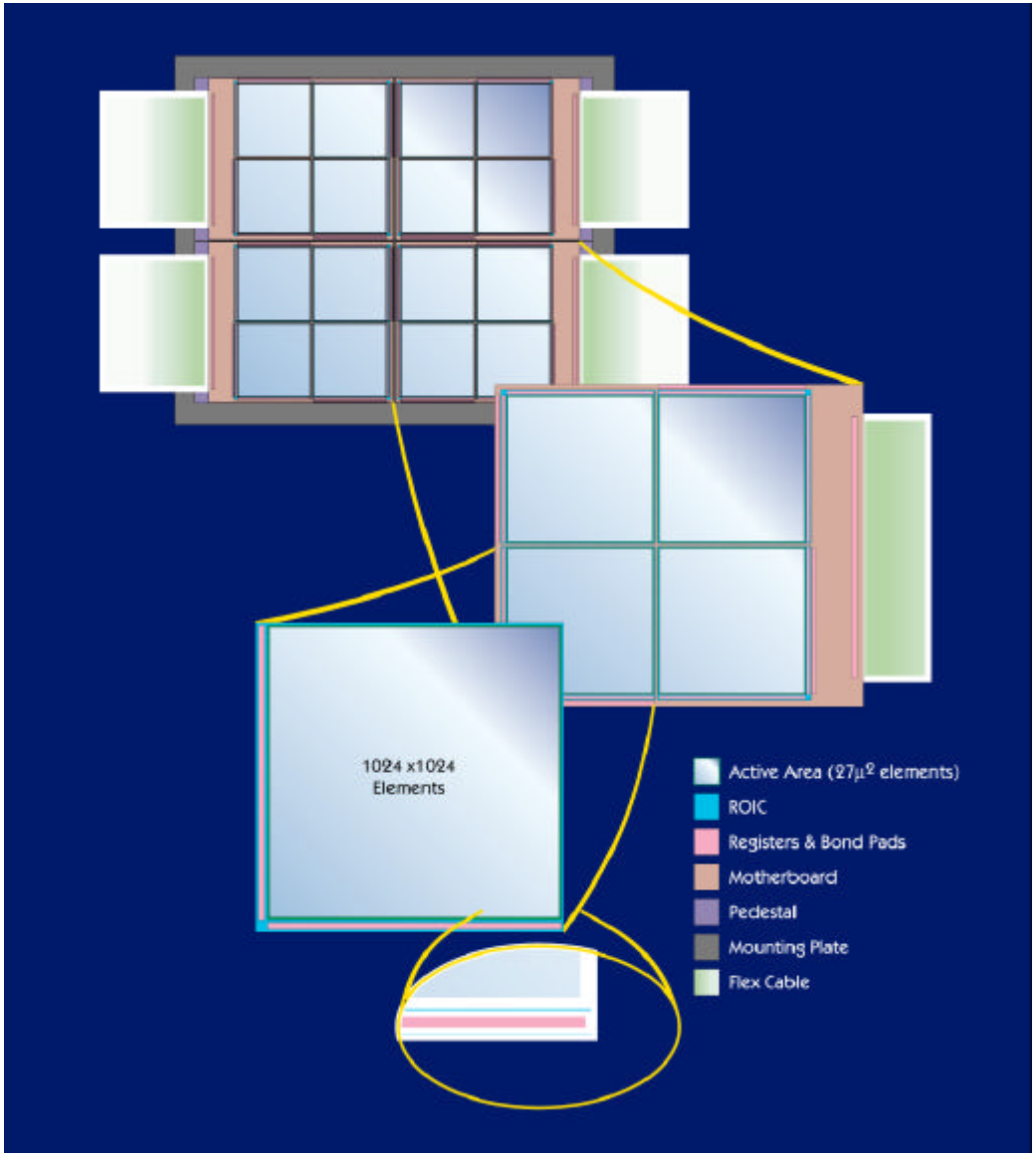
4096 x 4096 Near-IR FPA Assemblies



Near-IR Quad-Camera FOV

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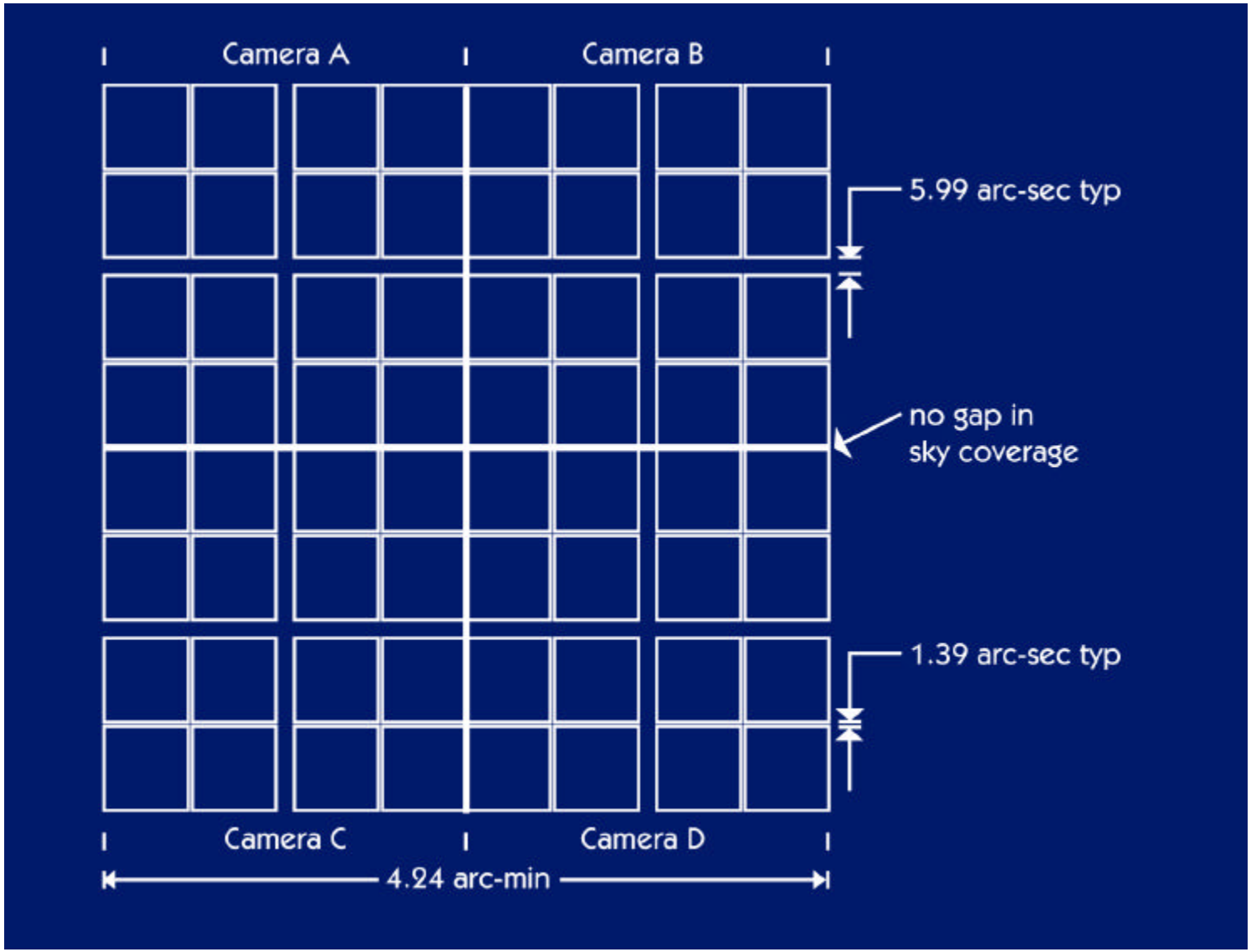

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Detector Technology Development

- Five technology development grants issued by NGST
- Near-ir 0.6 - 5 um
  - Raytheon IRCoE & University of Rochester
    - 1024 x 1024 InSb, buttable to 4k mosaic, 30K operation
  - Rockwell Science Center & University of Hawaii
    - 2048 x 2048 HgCdTe and Si p-i-n diodes, buttable to 4k mosaic, 30K operation
- Mid-ir
  - Raytheon IRCoE & NASA ARC & Cornell University
    - 512 x 512 Si:As, buttable to 1k mosaic, 6-8K operation, 5-28 um
  - Boeing Research & Technology Center
    - Si:Ga, 1k mosaic, 10-12K operation, 5-18 um
  - Rockwell Science Center & University of Rochester
    - HgCdTe, 25-30K operation, 5-10 um
- Funded by Ball Aerospace:
  - Raytheon IRCoE
    - 2048 x 2048 ROIC for InSb, low projected power dissipation

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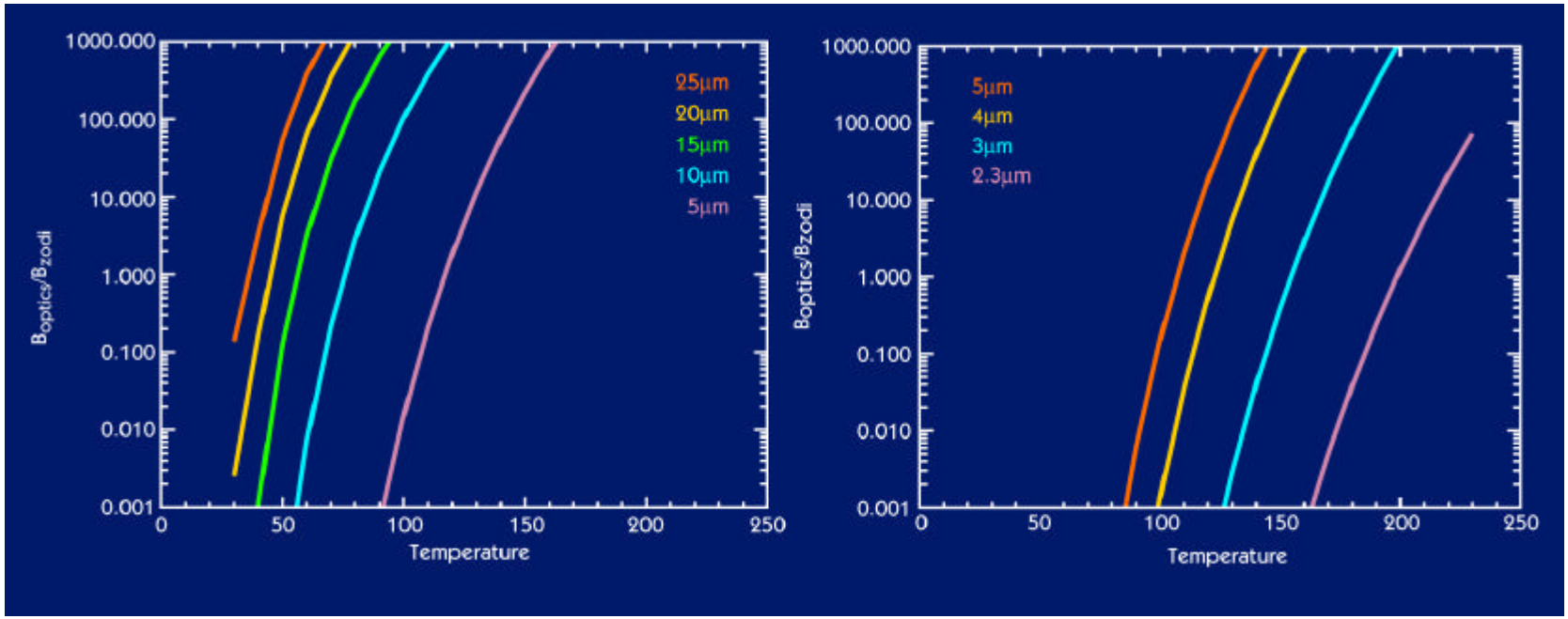
ISIM Cooling Requirements



ISIM optical bench temperature as a function of thermal background power relative to the Zodiacal light at various wavelengths.

Thermal Radiator Configuration

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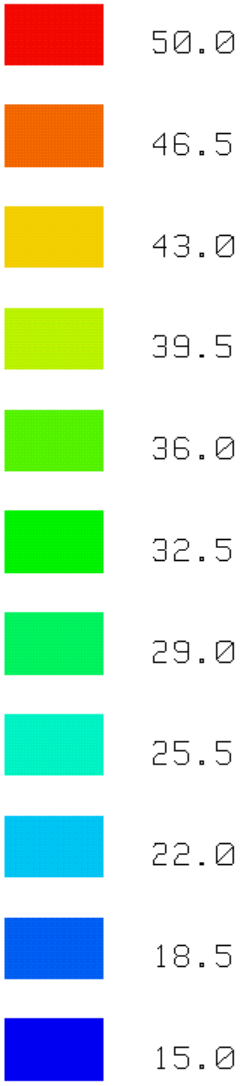

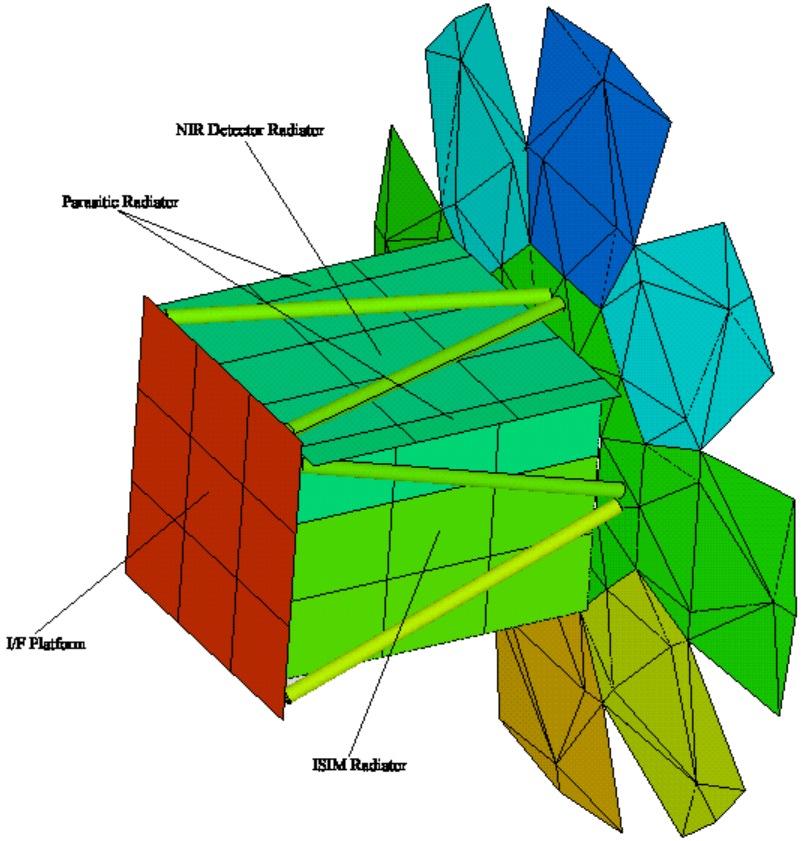

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NGST ISIM Top Level Heat Map

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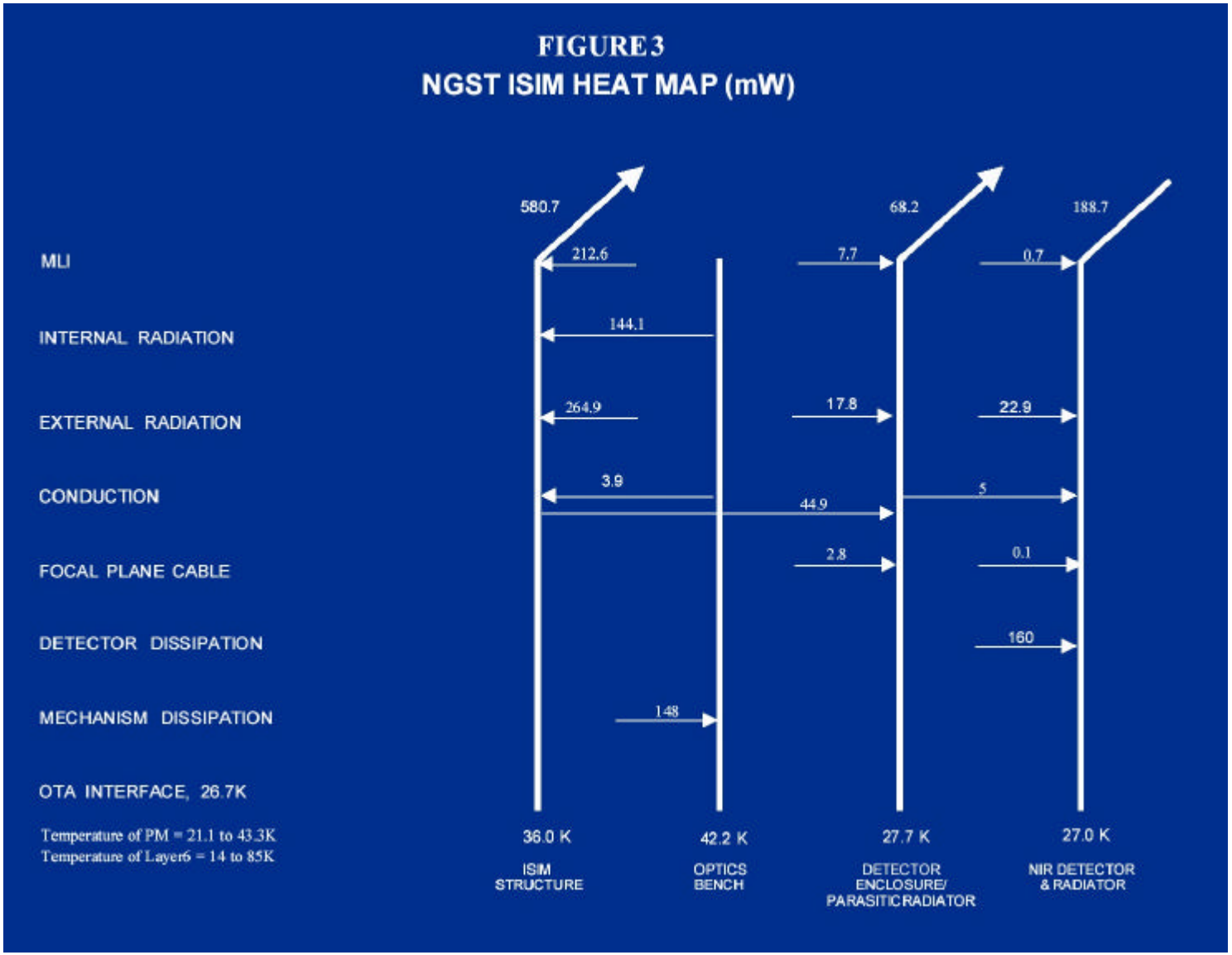

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ISIM Cooler Requirements

- Cooler required to enable any of the following design options:
  - warm (> 40 K) OTA
  - mid-infrared (> 5 micron) sensing with Si:As detectors
  - optical sensing with CCD detectors
- Exact requirements depend on options and involve two temperature regimes:
  - 0.6 watts of cooling at 25 K
  - 0.01 watts of cooling at 6 K
- Turbo-Brayton cooler technology developed by Creare Inc provide one of several solution paths

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Creare Miniature Turbo-Brayton Cooler

Key Features

- Vibration Free
- Robust gas bearings ensure long life
- Low mass, highly efficient, easy to integrate
- Ideal for use with radiatively cooled heat sink

Status

- 5 watt, 65 Kelvin engineering model has demonstrated long life
  - 70 K flight cooler produced for HST NICMOS
- 1 watt 35 K cooler demonstrated for the Air Force Research Lab

NGST Technology Development Goal

– 25K/ 6 K two stage demonstration cooler on life test by FY01

Funding

– Current development funded by NASA Cross Enterprise Technology
  - FY98: $525K, FY99: $1,075K, FY00: 1,535K
– NGST investment required in FY00 to meet goal

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Grass Roots Cost Estimate

- Independent of previous estimates
- Detailed estimate using GSFC grass roots costing system
  - Formulation and Implementation Phase (A,B,C,D,)

- Basis of Estimate
  - ISIM designed, constructed, qualified by GSFC and delivered to Prime Contractor as GFE
    - realistic mix of CS and contract labor assumed
  - SI modules designed, constructed, qualified by external SI teams and delivered to GSFC for integration into ISIM
    - average aerospace contractor rate assumed
      - derived from current Ball, TRW, and LM contracts
    - both engineering and science labor force included

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Grass Roots Cost Estimate

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WBS (Note 4)	Element	A	B	C/D	Launch	Total RY $K	Total FY96 $K
1.0	Management	585	1,306	2,743	740	5,374	4503
2.0	Science	889	3,164	11,936	3,962	19,952	15,775
3.0	Systems	571	1,774	3,406	467	6,219	5,138
4.0	SR&QA	302	942	2,202	597	4,043	3,408
5.0	Structure	420	4,737	26,905	764	32,827	26,184
6.0	Optics	0	9,467	27,161	789	37,417	30,061
7.0 (incomplete: note 1)	Electronics	372	1,860	14,645	599	17,476	14,337
8.0	Operations	0	0	0	0	-	-
9.0	Thermal	297	1,361	2,567	561	4,786	3,911
10.0 (incomplete: note 2)	Software	0	0	0	0	-	-
11.0	Detectors	266	18,916	23,095	72	42,349	34,918
12 (Note 3)	Cryo-cooler	15	305	9,735	968	11,023	8,572
Total Real Year $K		3,718	43,833	124,396	9,519	181,465	
Total FY96 $K		3,365	37,459	98,845	7,139		146,808

Notes

1. flight science processor
2. flight software
3. 25/6K two stage fully redundant
4. I&T distributed throughout

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Grass Roots Cost Estimate

Module	A	B	C/D	Launch	Total RY $K	Total FY96 $K
ISIM Integrator (incomplete: notes 1,2)	1,194	6,245	39,915	4,274	51,628	41,954
NIRCAM (incomplete: note 2)	1,064	19,287	39,014	1,751	61,117	49,635
NIRSPEC (incomplete: notes 2,3)	720	8,835	22,659	1,836	34,050	27,323
MIRCAM (incomplete: note 2)	740	9,466	22,884	1,658	34,749	27,896
Total Real Year $K	3,718	43,833	124,473	9,519	181,544	
Total FY96 $K	3,365	37,459	98,845	7,139		146,808

Notes
1. flight science processor
2. flight software
3. micro-mirror array

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Cost Comparisons

WBS Element	GSFC ISIM 98	GSFC CAN 96	ISIM98 - CAN	Company A	ISIM98 - A	Company B	ISIM98 - B
Management	4503	0	4,503				
Science	15,775	4,500	11,275				
Systems	5,138	NA					
SR&QA	3,408	NA					
Structure	26,184	18,700	7,484				
Optics	30,061	8,600	21,461				
Electronics	14,337	13,200	1,137				
Operations	pending	0					
Thermal	3,911	0	3,911				
Software	pending	5,800					
Detectors	34,918	40,900	-5,982				
Cryo-cooler	8,572	2,600	5,972				
I&T	distributed	14,300					
Design	NA	NA					
F&A	NA	NA					
matls/S/C/ODC	NA	NA					
Total FY96 $K	**146,808**	**108,600**	38,208				
FY96 w/o Science	131,033						

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FY98 accomplishments

- modular opto-mechanical layout solution
- accurate thermal model
- realistic design layout
  - technical budget assessment: volume, mass, power
  - grass roots cost estimate
  - ISIM requirements on OTA and SSM
- provide engineering context for NRA, ESA, and CSA studies

FY99 goals

- development schedule
  - for ISIM
  - for FPAs and other technology development components
- SI and OTA interface definitions
- structural analysis
  - concept validation
  - material trade
- confirm ISIM volume requirement
  - thermal mechanical layout
  - scattered light analysis
- develop synergism with NRA, ESA, and Prime Contractor study teams